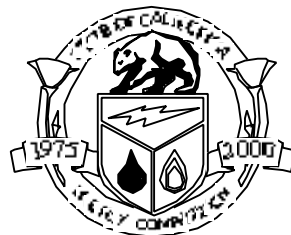


Contractor's Report

2001 UPDATE CALIFORNIA NONRESIDENTIAL ENERGY EFFICIENCY STANDARDS

Task 1 Report: Measure Identification and Analysis Plan

AUGUST 2000



Gray Davis, *Governor*

**CALIFORNIA
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**California Energy Commission
2002 Title 24 Building Energy Efficiency Standards**

Contractor Report

**2001 Update – California Nonresidential Energy Efficiency Standards
Task 1 Report: Measure Identification and Analysis Plan**

Energy Commission Publication No. P400-00-014

This Contractor Report, prepared by Eley Associates under Commission Contract No. 400-00-05, identifies energy efficiency measures for nonresidential buildings from the American Society of Heating, Ventilating and Air Conditioning Engineers (ASHRAE) Standard 90.1-1999, and evaluates the applicability of these measures for incorporation into California's 2002 Title 24 Building Energy Efficiency Standards. This report is intended to be used as the basis for discussion at a Staff Workshop to be held at the California Energy Commission on September 8, 2000, on the proposed 2002 Title 24 Building Energy Efficiency Standards.

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2001 Update

California Nonresidential Energy Efficiency Standards

Task 1 – Measure Identification and Analysis Plan

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Introduction

This document identifies potential upgrades to the 1998 California Energy Efficiency Standards (California 1998). It is background for a public workshop to be held at the Energy Commission on September 8. The potential upgrades are based on the national standard, ASHRAE/IESNA Standard 90.1-1999 (ASHRAE 1999), which was recently adopted and approved as an ANSI national consensus standard. The following features of ASHRAE 1999 are improvements over California 1998 and will be considered as possible upgrades to the nonresidential energy efficiency standard. The plan is for these upgrades to be adopted by the Energy Commission in 2001 and to become effective in 2002. No changes are proposed to the residential standard.

- *Fenestration.* The California nonresidential fenestration requirements were last updated in 1992. At that time, the Energy Commission only considered clear and tinted glazing constructions in developing the criteria because of aesthetic issues related to reflective glass as well as cost and availability uncertainties related to low-e coatings. Fenestration technologies have improved in the last 10 years, the markets are more stable. By contrast, ASHRAE 1999 considered a wide variety of glazing constructions in determining the criteria, and as result, the criteria are more stringent and appropriate for modern technologies, especially with regard to reflective glass and low-e coatings.
- *Cool Roofs.* Cool roofs have both a high reflectance and a high emittance. The high reflectance keeps much of the sun's energy from being absorbed and becoming a component of heat transfer. The high emittance assures that when the roof does warm up, its heat can escape through radiation to the sky. Cool roofs are not considered in California 1998 as either a credit or the basis of the standard. However ASHRAE 1999 has credits for cool roofs that allow you to make trade-offs against roof insulation or other measures.
- *HVAC Equipment Efficiency.* ASHRAE 1999 has more stringent equipment efficiency requirements than California 1998 for HVAC equipment larger than about 5.4 tons¹. The ASHRAE efficiency requirements were justified through life-cycle cost analysis, using cost data provided by the American Refrigeration Institute (ARI). The equipment classifications are similar between ASHRAE 1999 and California 1998, the upgrade would be a simple matter of substituting efficiency values.
- *Air-Side Economizers.* Air-side economizers have great energy savings potential in California, but have a history of malfunctioning, especially with small equipment. The language in ASHRAE 1999 is more flexible with regard to air-side economizers. It is more specific about the type of controls that may be used, has a more efficient exception for small systems, and includes a trade-off that permits a high efficiency unit to be used in lieu of an economizer.
- *Cooling Towers.* ASHRAE 1999 requires two-speed fan control for cooling towers, while California 1998 has no requirements for cooling towers.
- *Performance Testing and Completion.* California 1998 requires that operation and maintenance information be provided to the building owner, while ASHRAE 1999 goes further. It explicitly requires HVAC system balancing, is more specific about the contents of owner's manuals, and requires commissioning plans to be developed for projects larger than 50,000 ft².
- *Simplified HVAC Approach.* Packaged single-zone HVAC equipment represents as much as 80% of the market and the majority of the HVAC requirements in both ASHRAE 1999 and California 1998 to not apply to these "simple" systems. ASHRAE recognizes this and provides a simplified approach that is easy to use and apply.

¹ Equipment small than this is regulated by NAECA which preempts the development of efficiency requirements by states and local governments.

Economic Assumptions

California

The Energy Commission is required by law to develop and maintain energy efficiency standards that are “ . . . cost effective, when taken in their entirety, and when amortized over the economic life of the structure when compared with historic practice”.² The economic assumptions used in previous life-cycle cost analysis are documented in “*Summary of Cost Effectiveness Methodology and Assumptions*”, Building and Appliances Efficiency Office, California Energy Commission, March 29, 1990. The key points in this document are as follows:

- If a measure reduces overall life-cycle cost, then it is considered to be cost effective.
- Life cycle cost of measures shall be calculated as follows:

$$\text{Change in Life-Cycle Cost} = \text{Change in Initial Cost} - \text{Present Value of Electricity Cost Savings} - \text{Present Value of Gas Cost Savings}$$
- The present value of electricity and gas cost savings shall be calculated as follows:

$$\text{Present Value of Electricity Cost Savings} = \text{Energy Saved Per Year} - \text{Present value of the cost of energy over the measure}$$
- Energy costs were based on projections made by the Energy Commission forecasting group in 1990. The present value of a kWh of electricity saved over the life of a nonresidential building was determined to be \$1.04. The present value of a therm of natural gas saved over the life of a nonresidential building was determined to be \$6.47. These values will have to be updated for the 2001 update.
- The above present value terms consider a real discount rate of 3% and a building life of 15 years. For low-rise residential, the building life was assumed to be 30 years. A shorter life was used for nonresidential buildings because of high tenant turn over (churn rate) and the life of nonresidential HVAC equipment. The approach taken in 1992 does not directly account for measure life or persistence. For nonresidential buildings, this is the primary reason that a short 15 year life was used in the analysis.

ASHRAE

Most of the requirements in ASHRAE 1999 were justified with life-cycle cost analysis. The ASHRAE approach to life cycle cost is simple. This is based on the concept of a scalar ratio. The scalar ratio accounts for the discount rate, study period (building life), and other factors. The following equations shows how life-cycle cost was calculated.

$$\text{Change in Life-Cycle Cost} = \text{Change in Initial Cost} - \text{Scalar Ratio} \left(\text{Annual Electricity Cost Savings} + \text{Annual Gas Cost Savings} \right)$$

The scalar ratio combines the effects of equipment life, discount rate, fuel escalation rates, federal and state tax rates, down payment, and financing costs. The scalar ratio is applied to the annual energy costs for each measure in a fashion similar to a series present worth factor. Annual energy costs are determined using the estimated annual energy use for a measure and national average fuel prices of \$0.08/kWh for electricity and \$0.56/therm for natural gas. Because the analysis considered incremental changes in measure efficiency, maintenance and installation costs for each incremental change were assumed to be zero.

ASHRAE used a scalar ratio of 8 for the development of all criteria. Using the ASHRAE scalar ratio and national average energy prices, the effective present worth of a kWh of electricity saved over the life of the

² Warren Alquist Act, Section 25402.

building is approximately \$0.64, while the effective present worth of a therm of gas saved over the life of the building is \$4.48.

Comparison

Table 1 compares the present value of electricity and gas savings between ASHRAE 1999. If everything else in the analysis is equal, e.g. measure cost, savings models, etc., then it is possible to justify a greater investment in energy efficiency using the California criteria for economic performance. The value of electricity savings (based on the 1992 data) is 63% higher and the value of gas savings is 44% higher.

Table 1 – Comparison of ASHRAE 1999 and California Standards for Economic Performance

	<i>Present Value of a kWh of Electricity Saved Over the Building Life</i>	<i>Present Value of a Therm of Gas Saved Over the Building Life</i>
<i>California</i>	<i>\$1.04</i>	<i>\$6.47</i>
<i>ASHRAE 1999</i>	<i>\$0.64</i>	<i>\$4.48</i>
<i>Increase in Value of Savings</i>	<i>63%</i>	<i>44%</i>

Since the ASHRAE methodology values energy savings less than the Energy Commission, it follows that most of the requirements in ASHRAE 1999 should be cost effective for California. In addition, the ASHRAE requirements were subjected to three extensive public reviews and were developed using ANSI standards for consensus documents.

Fenestration

The ASHRAE 1999 fenestration criteria is more stringent than California 1998. The California fenestration criteria has not been updated since the 1992 adoption, and at that time only uncoated tinted glass was considered in developing the criteria. The ASHRAE 1999 criteria, by contrast, is based on modern low-e and specularly selective coatings, advanced spacer and frame technology, suspended films and other glazing technologies that are available to today's designers. The main difference between California 1998 and ASHRAE 1999 is the criteria for solar heat gain coefficient (SHGC). The U-factor criteria are similar.

Climate Categories

In order to make a comparison between the stringency of California 1998 and ASHRAE 1999, the differences in how climate is accounted for must be addressed. California 1998 has separate criteria for five climate regions described in the bullets below.

- South Coast (Zones 6 through 10)
- North Coast (Zones 2 through 5)
- Central Valley (Zones 11 through 13)
- Desert (Zones 14 and 15)
- Mountains (Zone 1 and 16)

The building envelope criteria in ASHRAE 1999 are specified separately for 26 different temperature bins. The temperature bins are defined in terms of heating degree days at base 65°F (HDD65) and cooling degree days at base 50°F (CDD50). Figure 1 shows the 26 temperature bins used to organize the ASHRAE 1999 criteria for the building envelope. The temperature bins that are shaded in light gray occur in California. These include 5, 6, 7, 8, 9, 11, 12, 14 and 15. Figure 2 shows a close-up of the California temperature bins with the name of an example city that falls in each bin.

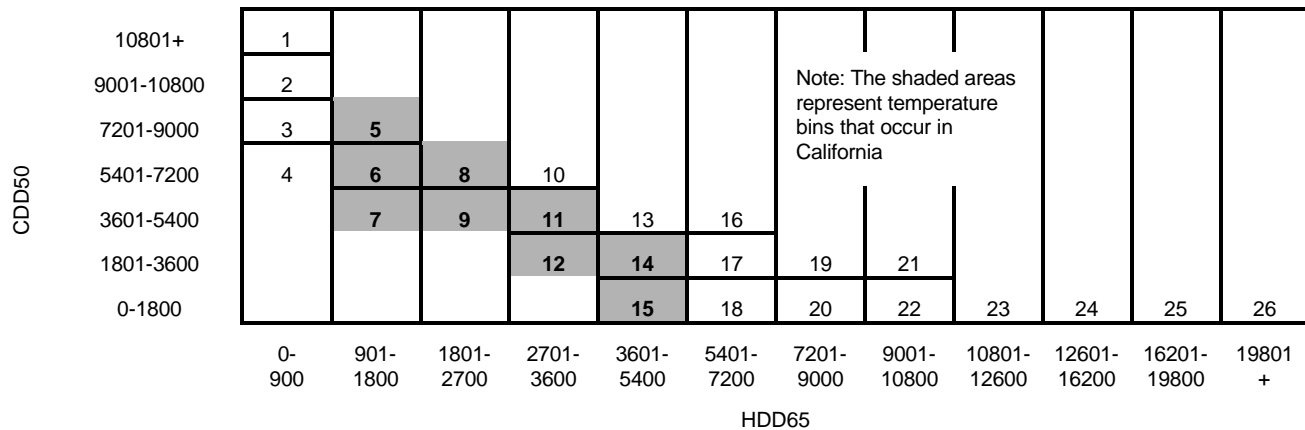


Figure 1 – ASHRAE Temperature Bins

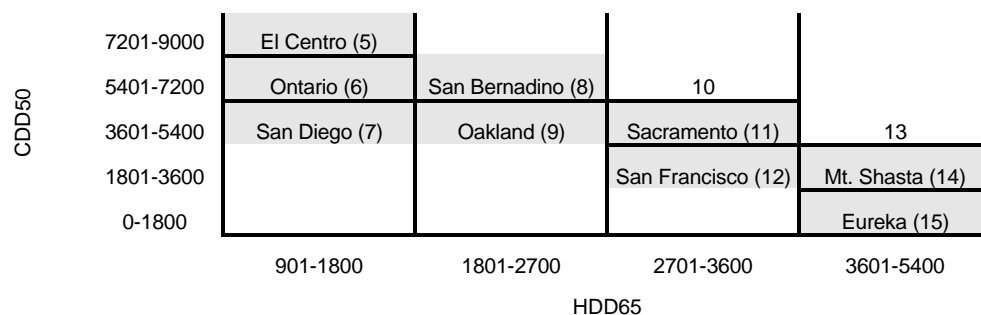


Figure 2 – California Temperature Bins with Example Cities

Figure 3 shows the relationship between the five California regions, the 16 California climate zones and the ASHRAE temperature bins. Note that there is not a one-to-one relationship. Some California zones include more than one ASHRAE temperature bin and some ASHRAE temperature bins include more than one California climate zone.

		ASHRAE 1999 Temperature Bins								
Region	Zone	15	12	9	7	6	11	8	5	14
Mount.	1	Eureka								
North Coast	2		Petaluma				Ukiah			
	3		San Fran.	Oakland						
	4			San Jose						
	5		Santa Maria	San Luis O.						
South Coast	6			Oxnard	Long Beach					
	7			Oceanside	San Diego					
	8					Santa Ana				
	9				L. A.	Pasadena				
	10					Ontario		San Bern.		
Central Valley	11						Redding			
	12						Sacramento			
	13							Bakersfield		
Desert	14						Palmdale			
	15								El Centro	
Mount.	16									Truckee

Figure 3 – Relationship Between ASHRAE Temperature Bins and California Climate Regions

Note: The ASHRAE Temperature Bins are Grouped to Show the Relationship to California Regions

Comparison of California 1998 and ASHRAE 1999

The California 1998 fenestration requirements are basically unchanged since 1992. The requirements call for single tinted glass along the coast and double tinted in the central valley, the desert and in the mountains. However, north-facing fenestration can be clear. These requirements apply to all window-wall ratio (WWR) ranges below 40% and are the same for offices, retail, assembly and schools. Tables 2 and 8 summarize the 1998 California building envelope requirements.

Table 2 – Summary of Title 24 Nonresidential Building Envelope Requirements*Note: The residential criteria are identical to the nonresidential criteria, except for the shaded areas.*

		North Coast	South Coast	Central Valley	Desert	Mountains
Climates		2, 3, 4, 5	6, 7, 8, 9, 10	11, 12, 13	14, 15	1, 16
Windows	U-factor	1.23	1.23	0.72	0.72	0.72
	SHGC-north	0.82	0.82	0.77	0.77	0.77
	SHGC-other	0.62	0.62	0.50	0.50	0.50
Skylights	U-factor	1.31	1.31	0.85	0.85	0.85
	SHGC-transparent	0.61	0.61	0.44	0.44	0.44
	SHGC-translucent	0.75	0.75	0.70	0.70	0.70

Table 3 – Summary of Title 24 Residential Building Envelope Requirements*Note: The residential criteria are identical to the nonresidential criteria, except for the shaded areas.*

		North Coast	South Coast	Central Valley	Desert	Mountains
Climates		2, 3, 4, 5	6, 7, 8, 9, 10	11, 12, 13	14, 15	1, 16
Windows	U-factor	1.23	1.23	0.72	0.72	0.72
	SHGC-north	0.82	0.82	0.77	0.77	0.77
	SHGC-other	0.82	0.62	0.50	0.50	0.77
Skylights	U-factor	1.31	1.31	0.85	0.85	0.85
	SHGC-transparent	0.61	0.61	0.44	0.44	0.44
	SHGC-translucent	0.75	0.75	0.70	0.70	0.70

The ASHRAE 1999 fenestration requirements vary with WWR, e.g. the SHGC criteria becomes more stringent as the WWR becomes larger. The U-factor criterion is the same, however, for all WWR ranges. Like California 1998, ASHRAE 1999 has separate criteria for nonresidential and residential spaces. The fenestration U-factor requirements are very similar to California, e.g. single glass is required along the coast and double glass for the central valley, mountains and desert. However, the ASHRAE 1999 SHGC criteria are considerably more stringent than California. Tables 4 and 5 compare the U-factor and SHGC for California 1998 and ASHRAE 1999. This comparison is only for vertical fenestration (i.e. windows). A similar comparison will be made for skylights later in the update project.

Table 4 – Vertical Fenestration Stringency Comparison – Nonresidential

Criteria	Calif. Coast	Bin 6	Bin 7	Bin 9	Bin 12	Calif. Other	Bin 5	Bin 8	Bin 11	Bin 14	Bin 15
U-factor, Fixed	1.23	1.22	1.22	1.22	1.22	0.72	1.22	1.22	0.57	0.57	0.57
U-factor, Operable	1.23	1.27	1.27	1.27	1.27	0.72	1.27	1.27	0.67	0.67	0.67
SHGC, 10 WWR	.62	0.39	0.61	0.61	0.61	0.50	0.25	0.39	0.39	0.49	0.49
SHGC, 20 WWR	.62	0.25	0.61	0.39	0.61	0.50	0.25	0.25	0.39	0.39	0.49
SHGC, 30 WWR	.62	0.25	0.44	0.39	0.61	0.50	0.25	0.25	0.39	0.39	0.49
SHGC, 40 WWR	.62	0.25	0.44	0.34	0.39	0.50	0.25	0.25	0.39	0.39	0.49
SHGC North, 10 WWR	.82	0.61	0.82	0.82	0.82	0.77	0.61	0.61	0.49	0.49	0.49
SHGC North, 20 WWR	.82	0.61	0.61	0.61	0.82	0.77	0.61	0.61	0.49	0.49	0.49
SHGC North, 30 WWR	.82	0.61	0.61	0.61	0.61	0.77	0.61	0.61	0.49	0.49	0.49
SHGC North, 40 WWR	.82	0.61	0.61	0.61	0.61	0.77	0.61	0.61	0.39	0.49	0.49

Table 5 – Vertical Fenestration Stringency Comparison – Residential

Criteria	Calif. Coast	Bin 6	Bin 7	Bin 9	Bin 12	Calif. Other	Bin 5	Bin 8	Bin 11	Bin 14	Bin 15
U-factor, Fixed	1.23	1.22	1.22	1.22	1.22	0.72	1.22	1.22	0.57	0.57	0.57
U-factor, Operable	1.23	1.27	1.27	1.27	1.27	0.72	1.27	1.27	0.67	0.67	0.67
SHGC, 10 WWR	.82	0.61	0.61	0.61	0.61	0.77	0.39	0.39	0.39	0.49	0.72
SHGC, 20 WWR	.82	0.44	0.61	0.61	0.61	0.77	0.25	0.39	0.39	0.39	0.72
SHGC, 30 WWR	.82	0.44	0.61	0.39	0.61	0.77	0.25	0.25	0.39	0.39	0.51
SHGC, 40 WWR	.82	0.40	0.44	0.34	0.61	0.77	0.25	0.25	0.39	0.39	0.51
SHGC North, 10 WWR	.82	0.61	0.82	0.82	0.82	0.77	0.61	0.49	0.49	0.72	0.49
SHGC North, 20 WWR	.82	0.61	0.61	0.61	0.82	0.77	0.61	0.49	0.49	0.72	0.49
SHGC North, 30 WWR	.82	0.61	0.61	0.61	0.82	0.77	0.61	0.49	0.49	0.72	0.49
SHGC North, 40 WWR	.82	0.61	0.61	0.61	0.82	0.77	0.61	0.49	0.49	0.72	0.49

Life Cycle Cost

General Approach

The committee developed the ASHRAE 1999 fenestration criteria with support from the Primary Glass Manufacturers Council and Eley Associates. The approach taken was similar to the approach taken to develop the other building envelope criteria (see Appendix A), although for fenestration the process was more complex, since for fenestration, there are three performance characteristics that must be considered simultaneously: U-factor, SHGC and visible light transmission (Tvis). Other envelope components such as roofs, floors, walls or slabs can be characterized with just one performance measure: U-factor or F-factor.

The following steps describe the general approach for developing the fenestration criteria.

1. Identify the candidate fenestration products that may be used in vertical and horizontal applications and calculate the performance characteristics for each in a consistent manner. The Window program from NFRC/LBNL was used to calculate the performance characteristics.

2. Collect cost data on each of the various fenestration products. A cost model was developed that assigns a cost premium to various glazing technologies and provides a method to calculate the cost for each fenestration product.
3. Develop an energy model that gives the relative energy performance of the candidate fenestration products and accounts for differences in:
 - a. U-factor, SHGC, and visible light transmission. The later is accounted for through the addition of a daylighting term in the energy savings models.
 - b. Residential, nonresidential and semi-heated space categories.
 - c. Fenestration orientation, in the case of windows.
4. Develop a subset of the records in the library of fenestration products that represent technologies intended primarily for reducing U-factor. These are clear products with low-e and other coatings intended to reduce thermal transmittance, as opposed to reducing SHGC.
5. Calculate the life-cycle cost of each of the U-factor subsets of fenestration products for a window-wall ratio (WWR) of 0.25 for vertical fenestration and a skylight-roof ratio (SRR) of 0.05. The fenestration product with the lowest LCC is used to set the U-factor criteria for all fenestration area ranges. This process is repeated for each set of climate conditions.
6. Repeat the following steps for each fenestration area range. For vertical fenestration four ranges were considered: 0-10%, >10-20%, >20-30%, and >30-40%. For skylights, two fenestration area ranges were considered: 0-2% and >2-5%.
 - a. Create a subset of fenestration products from the library that have a U-factor lower than that determined in the above step. This set of constructions is the SHGC set and may vary for each temperature bin or climate zone.
 - b. Calculate the life-cycle cost of each fenestration product in the SHGC subset determined above. The fenestration product with the lowest LCC is used to set the SHGC criteria.
7. Review the criteria that resulted from the above steps and apply professional judgment. This step resulted in “smoothing” some of the criteria to provide better consistency between temperature bins and fenestration ratios.

Database of Constructions

A comprehensive database of constructions was developed as part of the process. This list is included as Appendix B to this document. The database was developed with input from members of the ASHRAE committee, which included engineers from glass manufacturers and coaters. Performance data for each of the fenestration products was calculated using the Window computer program, available from NFRC/LBNL.

Cost Model

The life cycle cost approach requires that each fenestration construction be assigned a cost. For this, a cost model was used which has a cost premium for various technologies. Tables 6 and 7 have the data for the cost models for glass and plastic constructions.

Table 6 - Glass Fenestration Cost Premiums

Item	Code	Cost Premium (\$/ft ²)
Markup	MUP	1.30
Tint	TNT	0.39
Double	DBL	3.02
Eclipse	ECL	1.68
SS-08	SS8	1.81
Low-E	LOE	1.88
Thermal Break	BRK	1.50
Vinyl Frame	VNL	4.00
Heat Mirror	HM	6.35
High Perf. Tint	HPT	1.10
Visionwall	VIS	12.00
Thrm Brk + Spcr	BR3	2.30
Vinyl + Spcr	VN3	4.80
Metal +Spcr	MT3	0.80

For plastic skylights, the list of constructions and the associated cost and performance data is based on acrylic skylights. Non-glass skylights are also made of fiberglass and polycarbonate, but these are far less common and are not considered in this optimization. Performance data is taken from several sources. U-factors are taken from Table 5 of the 1993 *ASHRAE Fundamentals Handbook*. These numbers are consistent with the values used for glass skylights. Shading coefficient and light transmission data are taken from manufacturer's literature. Cost assumptions for plastic skylights are summarized in the following table.

Table 7 - Cost Assumptions for Plastic Skylights

Item	Code	Cost Premium (\$/ft ²)
Markup	MUP	1.30
Acrylic double	ADbl	2.00
Acrylic triple	ATrp	4.00
Acrylic thermal break	ABrk	0.70
Acrylic bronze	ABrz	0.50
Acrylic high white	AHW	0.50
Acrylic medium white	AMW	0.50
Acrylic low white	ALW	0.50

Life-Cycle Cost Model and Economic Assumptions

A simple method was used to calculate life-cycle cost for ASHRAE 1999.

$$LCC_i = Cost_i + ScalarRatio \cdot \left(kWh_i + kWh_{Lights} \right) \cdot P_E + Therms_i \cdot P_G$$

where

LCC_i The life-cycle cost of the i^{th} fenestration product considered in the analysis.

$Cost_i$ The initial cost of the i^{th} fenestration product.

KWh _i	The annual heating and cooling energy associated with the i th fenestration product. This is calculated on the basis of a square foot of exterior wall for vertical fenestration or a square foot of roof for skylights. See the discussion of the energy model below for how this is calculated.
KWh _{Lights}	The annual lighting energy associated with the i th fenestration product.
Therms _i	The annual gas use associated with the i th fenestration product. This is calculated on the basis of a square foot of exterior surface (including opaque). See the discussion of the energy model below for how this is calculated.
ScalarRatio	This is an economic factor that accounts for the life of the measure, the discount rate, and other factors. It is similar to a series present worth factor (SPWF). For ASHRAE 1999, this was set to 8.0 for development of all criteria.
P _E	The average price per kWh of electricity. ASHRAE used a national average price of \$0.08/kWh.
P _G	The average price per therm of natural gas. ASHRAE used a national average price of \$0.56/therm.

Energy Model

Heating and Cooling Energy

In the ASHRAE procedure, regression equations were used to calculate the energy use or savings related to various construction assemblies. The derivation of the equations for vertical fenestration are documented in the paper titled "Fenestration Optimization for Commercial Building Energy Standards" from the *Thermal Performance of the Exterior Envelopes of Buildings V*, ASHRAE/DOE/BTECC Conference, Clearwater, Florida, December 1992. The same general methodology was used for skylights, although the equation coefficients were developed subsequent to the published paper.

The following equations give an estimate of annual electricity and fuel use as a function of fenestration U-factor, shading coefficient and percent fenestration..

$$\begin{aligned} \text{Therms}_i &= h_0 + h_1 \times \text{HDD}_{65} + h_2 \times \text{FR} \times \text{HDD}_{65} \times U_i + h_3 \times \text{FR} \times \text{HDD}_{65} \times \text{SC}_i \\ \text{kWh}_i &= c_0 + c_1 \times \text{CDD}_{50} + c_2 \times \text{FR} \times \text{CDD}_{50} \times \text{SC}_i \end{aligned}$$

Where,

kWh_i = Annual electricity use with the ith skylight construction (kWh/ft² of wall or roof area).

Therms_i = Annual fuel use with the ith skylight construction (therms/ft² of wall or roof area).

HDD₆₅ = Heating degree days at base 65°F for a particular climate zone.

FR = For skylights, this is the ratio of skylight area to floor area ratio. For windows, this is the ratio of window area to gross exterior wall area.

U_i = The U-value of the ith skylight construction, (Btu/(h×ft²×°F)).

SC_i = The shading coefficient of the ith skylight construction.

CDD₅₀ = Cooling degree days base 50°F for a particular climate zone.

When the equations were developed, shading coefficient (SC) was still commonly used as the figure of merit for solar gains through fenestration. However, solar heat gain coefficient (SHGC) is used in the ASHRAE

1999. The original equations or the underlying database were not recalculated. Instead, a simple multiplier of 0.86 was used to translate shading coefficient to solar heat gain coefficient³.

$$\text{SHGC} = \text{SC} \times 0.86$$

$$\text{SC} = \text{SHGC} \times 1.16$$

The 0.86 factor was based on a review of Window 4.0 results for a selection of fenestration products used in the ASHRAE life-cycle cost analysis. It is not exact, because the ratio varies between 0.85 and 0.87 depending on the type of glazing. SHGC does not necessarily include the impact of the frame type, although just like SC, it can be defined to include the frame. In Window 4.0, SHGC and SC are reported for the glazing alone as well as for the total fenestration system.

Daylighting Credit

The ASHRAE methodology gives a credit for fenestration products that have a high visible light transmission (T_{vis}), relative to other fenestration products. Without this credit, the methodology would not distinguish between fenestration products with different light transmissions. Even though daylighting controls may not be installed or used, there is a benefit to having windows with a high light transmission, all else being equal. This benefit is accounted for in a lighting term associated with each fenestration product.

The daylighting credit for windows is documented in *Thermal Performance of the Exterior Envelopes of Buildings V*, ASHRAE/DOE/BTECC Conference, Clearwater, Florida, December 1992. The credit is summarized in the following equation. The savings depend on the visible transmittance, the fenestration area, the design illuminance for the lighting system, and for skylights, the configuration of the skylight well.

The equation for lighting energy is given below:

$$\text{kWh}_{\text{Lights}} = \text{LPD} \cdot \text{Hours} \cdot (1 - K_d)$$

where

$\text{kWh}_{\text{Lights}}$ The electric energy use associated with a square foot of window wall. This is based on assumptions on floor-to-floor height,

LPD Lighting power density in W/ft^2 .

Hours Full time equivalent lighting hours.

K_d Daylight savings factor (see below)

The daylight savings fraction is calculated using the following equation.

$$K_d = [\phi_1 + \phi_2 (C / T_{\text{vis}})] [1 - e^{-(\phi_3 + \phi_4 \cdot C) \text{FR} \cdot T_{\text{vis}} \cdot \text{WF}}]$$

where

K_d = daylight savings fraction (unitless).

T_{vis} = visible light transmission of the fenestration (unitless),

FR = fenestration ratio (unitless). For skylights, this is the ratio of the skylight area to the area of the roof. For windows, this is the window-wall ratio.

WF = well factor (unitless). Assumed to be 0.6 in LCC analysis for plastic skylights and 0.8 for glass skylights. This is assumed to be 1.0 for windows.

C = design illumination (footcandles),

ϕ_n = coefficients developed through regression analysis. The coefficients vary between windows and skylights.

³ The two indices are similar, but SC represents the solar heat gain relative to 1/8" clear glass, while SHGC is the fraction of incident solar gain relative to no glass at all (air). For 1/8" clear glass the SC is 1.0, and the SHGC is about 0.87.

Overhangs and Side Fins

Overhangs and/or side fins are not considered in the life-cycle cost analysis. Both California 1998 and ASHRAE 1999 give credits for overhangs in the compliance process, but they were omitted from the life-cycle cost analysis because they are not possible on all buildings, and a low SHGC can be achieved through selection of a fenestration product. See Equation 1-B of California 1998 or Table 5.3.2.3 of ASHRAE 1999.

Preliminary Recommendation

This section includes preliminary recommendations on how ASHRAE 1999 will be used to update California 2001. The prescriptive tables would be updated and these tables would become the new basis for the building envelope trade-off option as well as the whole building compliance method.

Approach

The same general approach is recommended for California 2001. Recommended exceptions to the ASHRAE method are described below.

Energy Model

The ASHRAE energy model was developed to accommodate all climates from inside the arctic circle to the equator. A better model can be developed for California that is specific to California climates. The recommended new energy model would have a set of coefficients for each climate zone. The form of the equations would be as follows:

$$\Delta Therms_i = h_{2,J} \times FR \times U_i + h_{3,J} \times FR \times SHGC_i$$

$$\Delta kWh_i = c_{2,J} \times FR \times SHGC_i$$

where

$\Delta Therms_i$	Gas savings in therms
$h_{2,J}$ $h_{3,J}$ $c_{2,J}$	Climate specific coefficients, e.g. J is a reference to a particular climate zone
FR	Fenestration ratio
U_i	U-factor of the i^{th} fenestration product
$SHGC_i$	SHGC of the i^{th} fenestration product
ΔkWh_i	Electricity savings in kWh

The recommended equations are structurally identical to those used in the ASHRAE process, but are tailored to the specific conditions of California. The constant terms are dropped from these equations, since they will cancel out when the life-cycle cost of two or more construction assemblies are compared. The California specific coefficients will be developed from DOE-2 simulations of prototype buildings. In the above equations “J” is reference to a specific California climate zone.

It is recommended that the ASHRAE 1999 daylighting models and assumptions be used in the California, with no modifications.

Database of Fenestration Products

The database of constructions will be reviewed at workshops and modified if comments warrant. As with earlier Title 24 Standards, reflective glazing will not be considered due to restrictions in some locales (e.g. San Francisco) and architectural considerations. Proprietary glazing products (those offered by only one manufacturer) also will not be considered. Technologies that will be considered include: tinting, double glazing, and low-E coatings (both for single and double glazing).

Cost Model

The cost data will be reviewed with the major glass manufacturers and fabricators to verify that the data are valid for California. The data will also be reviewed at public workshops.

HVAC Downsizing

Advanced glazing products, especially those that reduce SHGC can enable smaller HVAC systems to be installed. The HVAC savings can off-set the cost of the advanced glazing. This credit was not considered in either the ASHRAE 1999 or the California life cycle cost analysis. However, these benefits are real and will be considered in the analysis⁴.

Cool Roofs

Cool roofs have both a high reflectance and a high emittance. The high reflectance keeps much of the sun's energy from being absorbed. The high emittance allows radiation to the sky.

Cool roofs are typically white and have a smooth texture. Commercial roofing products that qualify as cool roofs fall in two categories: single ply and liquid applied. Examples of single ply products include:

- White EPDM (Ethylene-Propylene-Diene-terpolymer Membrane)
- White PVC (polyvinyl chloride)
- White CPE (chlorinated polyethylene)
- White CPSE (chlorosulfonated polyethylene, e.g. Hypalon)
- White TPO (thermoplastic polyolefin)

Liquid applied products may be used to coat a variety of substrates. Products include:

- White elastomeric coatings
- White cementitious coatings
- White acrylic coatings

Cool roof benefits include lower cooling energy, lower peak cooling demand and potentially longer roof life due to lower surface temperature. In addition to the benefits within the building, a cool roof can reduce temperatures in the local urban environment.

Comparison of California 1998 and ASHRAE 1999

California 1998 offers no compliance credit for reflective roofs. The roof insulation requirements are based on calculations assuming a roof surface absorptivity of 0.7, and Alternative Compliance Method calculations must use the same assumption.

Standard 90.1 Roof Requirements

ASHRAE 1999 offers a credit for cool roofs that can be used with all compliance methods, including the prescriptive criteria, the building envelope trade-off method and the energy cost budget (ECB) method. The credit may be used to justify less roof insulation with the prescriptive method. The building envelope trade-off method allows the performance of any envelope component to be reduced. With the ECB method, trade-offs can be made against lighting, HVAC or other systems.

The credit is offered through an adjustment to the U-factor of the proposed roof. The adjustment or multiplier depends on climate. The code language from ASHRAE 1999 is included below:

⁴ A conservative credit could be offered based on low incremental costs of something like \$200 per ton of cooling and \$5 per 1000 Btu/h of heating.

5.3.1.1 Roof Insulation.

All roofs, including roofs with insulation entirely above deck, metal building roofs, and attics and other roofs, shall have a rated R-value of insulation not less than that specified in Table 5.3. Skylight curbs shall be insulated to the level of roofs with insulation entirely above the deck or R-5 (R-0.85), whichever is less.

Exception to 5.3.1.1: This exception applies to exterior roofs other than roofs with ventilated attics and does not apply to semiheated spaces. For demonstrating compliance, the U-factor of the proposed roof is allowed to be decreased by the multipliers in Table 5.3.1.1B provided the exterior roof surface:

1. has a minimum total solar reflectance of 0.70 when tested in accordance with ASTM E903, and
2. has a minimum thermal emittance of 0.75 when tested in accordance with ASTM E408.

Table 8 – Cool Roof U-factor Adjustments from ASHRAE

Table 5.3.1.1B

Roof U-Factor Multipliers for Exception to 5.3.1.1

HDD65	(HDD18)	Roof U-Factor Multiplier
0-900	(0-500)	0.77
901-1800	(501 - 1000)	0.83
1801 - 2700	(1001-1500)	0.85
2701 - 3600	(1501 - 2000)	0.86
> 3600	(>2000)	1.00

The ASHRAE U-factor multipliers depend only on heating degree days. The following table shows how the California climate zones fall into the ASHRAE HDD bins for cool roof credits. Many California zones cross the boundaries from one ASHRAE bin to another. However, the value of the multiplier varies little between the three middle ASHRAE bins: 0.83, 0.85, and 0.86. California climate zones 1 and 16 are the only two that fall into the highest HDD range, where the multiplier is 1.00. Therefore, the ASHRAE multiplier is close to 0.85 for most of California.

Region	CA Zone	ASHRAE 1999 HDD Bins (grouped by U-factor multiplier categories)				
		1 – 4 (HDD 0 – 900)	5 – 7 (HDD 900 – 1800)	8 – 9 (HDD 1800 – 2700)	10 – 12 (HDD 2700 – 3600)	13 – 26 (HDD 3600 +)
Mount.	1					Eureka
North Coast	2				Petaluma, Ukiah	
	3			Oakland	San Fran.	
	4			San Jose		
	5			San Luis O.	Santa Maria	
South Coast	6		Long Beach	Oxnard		
	7		San Diego	Oceanside		
	8		Santa Ana			
	9		L. A., Pasadena			
	10		Ontario	San Bern.		
Central Valley	11				Redding	
	12				Sacramento	
	13			Bakersfield		
Desert	14				Palmdale	
	15		El Centro			
Mount.	16					Truckee

Figure 4 – Relationship Between ASHRAE U-factor Multiplier HDD Bins and California Climate Regions

In addition to the prescriptive requirements, Standard 90.1 offers two performance alternatives: the building envelope trade-off option and the energy cost budget (ECB) method. The building envelope trade-off option allows tradeoffs between the performances of different elements of the envelope. The Energy Cost Budget method allows a whole-building performance tradeoff implemented through computer simulation. The calculation rules are described in a supplement to the Standard.

Credit for cool roofs is applied differently in the two performance alternatives. In the building envelope trade-off option, the prescriptive U-factor multiplier may be applied to the proposed roof construction and that adjusted U-factor may be used in the calculation. For the energy cost budget method, the budget building (minimum code complying building) is modeled with a roof reflectance of 0.3. If the proposed roof qualifies as a cool roof, then it may be modeled with a higher reflectance.

Title 24 Roof Requirements

Tradeoff equations are an alternative to the prescriptive envelope requirements. There are two equations: one for heat gain and the other for heat loss. They allow tradeoffs between the performances of all envelope components. The heat loss equations (1-C and 1-D in the Standard) are relatively simple UA calculations. As long as the product of U-factor and envelope component area is lower in the proposed building, then the project complies with the heat loss requirements.

In the heat gain equations (1-E and 1-F) each term is also multiplied by a “temperature factor” (for opaque elements) or a “solar factor” (for fenestration). Currently the heat gain equations do not have a term for surface absorptivity. The impact of the roof on heat gain is expressed by a function of the area, U-factor, and “temperature factor”.

$$A \times U \times TF$$

where

A = roof area

U = roof U-factor

TF = Temperature Factor, which depends on climate zone and roof construction heat capacity.

A third compliance option is an Alternative Compliance Method computer program. This is a Energy Commission certified simulation tool that compares the whole building performance of a standard building to a designer's proposed building. This approach allows tradeoffs between heating, cooling, lighting and water heating energy end-uses. Source energy is the currency for comparison.

Persistence and Eligibility Criteria

The performance of cool roofs depends on the surface conditions of the roof (reflectance and emissivity). The surface conditions deteriorate over time due to the accumulation of dirt, weather, and UV damage. The life of cool roofs and the persistence of energy savings is an important issue that must be considered.

All energy codes that include a credit for cool roofs must specify eligibility criteria that define exactly what is meant by a cool roof. Existing codes and programs all address this issue a little differently. One of the difficult issues is a lack of accelerated aging test standard to represent long-term performance. Therefore, most codes only use initial reflectance and emissivity as qualifications as the basis of eligibility criteria, but base the savings on an estimate of aged performance.

Unlike fenestration, there is currently no labeling program for the reflectance and emissivity of cool roofs nor is there any third-party verification of manufacturer claims.

Standard 90.1

The criteria for Standard 90.1 are listed above and repeated here. The referenced test standards are described briefly below. These same criteria are also used in the Guam Energy Code.

1. has a minimum total solar reflectance of 0.70 when tested in accordance with ASTM E903, and
2. has a minimum thermal emittance of 0.75 when tested in accordance with ASTM E408.

Standard 90.2

A proposal is being considered by ASHRAE to add a cool roof credit to Standard 90.2, which covers low-rise residential buildings. It is similar to the 90.1 criteria except that the reflectance threshold is 0.65 rather than 0.70, and Solar Reflectance Index (SRI) is offered as an alternative. LBNL is developing the SRI rating system to indicate the temperature of materials in the sun. The extremes of white and black paint define the SRI.

1. a minimum total solar reflectance of 0.65 when tested in accordance with ASTM E903 or E1918, and has a minimum thermal emittance of 0.75 when tested in accordance with ASTM E408 or C1371; or
2. has a minimum solar reflectance index (SRI) of 75 calculated in accordance with ASTM E1980 for medium wind-speed conditions.

The following figure illustrates the SRI for a number of roofing materials.

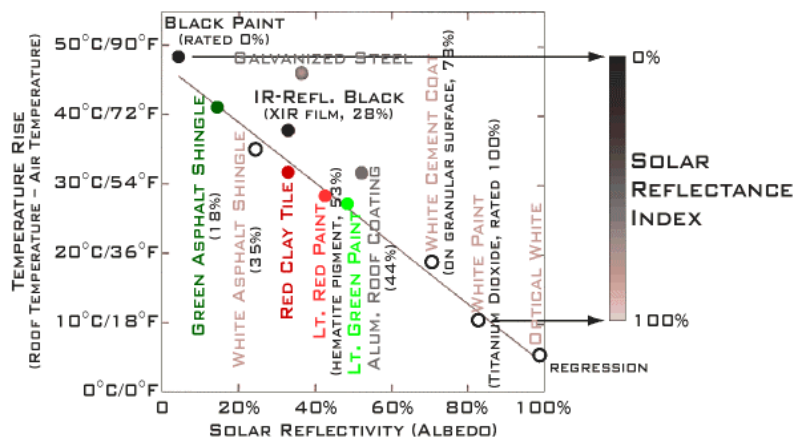


Figure 5 – Solar Reflectance Index and Solar reflectance of various roofing products

Source: Berdahl, 2000.

Energy Star

The EPA has an Energy Star Roof program. For roof products that may be applied to either low-slope or steep-slope roofs, such as roof coatings and single-ply membranes, Energy Star compliant products are required to have an initial solar reflectance of greater than or equal to 0.65, and a solar reflectance of greater than or equal to 0.50 after 3 years. For products only applicable to steep-slope roofs, Energy Star compliant products are required to have an initial solar reflectance of greater than or equal to 0.25, and a solar reflectance of greater than or equal to 0.15 after 3 years (US EPA, 1998). The Energy Star roof products program does not include emittance as a qualifying criterion. In order to use the Energy Star label, a manufacturer must sign a memorandum of understanding with the EPA that sets testing methods. Energy Star products must be tested using ASTM E 903 to measure initial reflectance. To measure aged reflectance of low-slope roofing products and coatings, manufacturers are required to use ASTM E 1918. To measure aged reflectance of steep-slope roofing products and coatings, manufacturers are required to use the procedure outlined by EPA, in the roof products MOU. Alternately, the manufacturer may test for solar reflectance of product after three years by taking samples from existing roofs as identified above, and having them tested per ASTM E903.

Florida

The State of Florida is now considering a cool roof provision for the energy code. Their criteria are minimum reflectance of 0.65 and minimum emissivity of 0.75.

Cool Roof Rating Council

The Cool Roof Rating Council (CRRRC) is working on standards that encompass both the reflectivity and emissivity of materials. CRRRC's first meeting was held in September 1997. CRRRC members include industry members, government representatives and researchers. For different roofing products, the group will provide information about initial reflectivity, durability of reflectivity, product durability, life-extension properties of coatings, and installation and compatibility issues (Pacific Energy Center, 1998). The CRRRC standards are not expected to be completed before the Title 24 rule-making process must be complete.

Test Standards

ASTM E408 – Standard Test Methods for Total Normal Emittance of Surfaces Using Inspection-Meter Techniques.

Developed by ASTM Committee E21 on Space Simulation and Applications of Space Technology.

ASTM E903 – Standard Test Method for Solar Absorptance, Reflectance and Transmittance of Materials Using Integrating Spheres.

Developed by ASTM Committee E44 on Solar, Geothermal and Other Alternative Energy Sources

ASTM E1918 – Standard Test Method for Measuring Solar Reflectance of Horizontal and Low-Sloped Surfaces in the Field.

ASTM E1918 was developed at LBNL under ASTM Subcommittee: E06.21 on Performance of Buildings. This test method covers the measurement of solar reflectance of various horizontal and low-sloped surfaces and materials in the field, using a pyranometer. The test method is intended for use when the sun angle to the normal from a surface is less than 45 degrees.

ASTM E1980 – Standard Test Method for Measuring Solar Reflectance of Horizontal and Low-Sloped Surfaces in the Field.

ASTM E1918 was developed at LBNL under ASTM Subcommittee: E06.21 on Performance of Buildings. This test method covers the measurement of solar reflectance of various horizontal and low-sloped surfaces and materials in the field, using a pyranometer. The test method is intended for use when the sun angle to the normal from a surface is less than 45 degrees.

Basis of the ASHRAE Cool Roof Credit

Cool roofs were not considered in setting the roof criteria for Standard 90.1-1999. Development of the roof criteria was based on a life-cycle cost analysis of common insulation techniques and materials. The base calculations assume that the roof absorptivity is 0.70 and DOE2.1E default emissivity of 0.9. The cool roof U-factor multipliers are intended to represent the optimal insulation level if the absorptivity is reduced to from 0.70 to 0.45 (representing an aged reflective roof). A several step process lead to the development of the multipliers included in the Standard. The approach is described briefly here. For details see the paper *Calculations for Reflective Roofs in Support of Standard 90.1*, Akbari, H, et al.

DOE-2 Simulations

DOE2.1E simulations were performed for two building types (nonresidential and residential) with three levels of insulation (R-0, R-11 and R-38) and four surface absorptivity values (0.95, 0.85, 0.55 and 0.25). These runs were repeated for 20 different climates. Three of those are in California: San Diego, San Bernardino and San Francisco. The models are similar to those used to develop the ASHRAE opaque envelope requirements, which is also similar to the model used to develop the requirements for Title 24 1992.

Regression Equations

The simulation results were used to develop regression equations for electricity and gas consumption. A separate set of coefficients was calculated for each climate and each of the two building types. The form of the equation is:

$$E_i = C_0 + C_1a + C_2U + C_3Ua$$

Where:

E_i = annual kWh, therms, or energy cost,

a = roof absorptivity,

U = roof U-factor,

C_0, C_1, C_2, C_3 = regression coefficients.

As an example the coefficients for San Diego are listed in the following table.

Table 9 – Regression Equation Coefficients for San Diego

	Residential Building				Nonresidential Building			
	C0	C1	C2	C3	C0	C1	C2	C3
Elec (kWh/ft2)	2.644	-0.227	-6.598	30.033	2.904	0.095	-3.837	18.416
Gas (therms/ft2)	-0.009	0.011	0.428	-0.4	0.001	0.002	0.348	-0.143
Cost (\$/ft2) assuming \$0.08/kWh and \$0.66/therm	0.206	-0.011	-0.245	2.139	0.233	0.009	-0.077	1.379

If the energy rates are assumed to be \$0.08/kWh and \$0.56/therm (as for Standard 90.1) and the roof U-factor is 0.1, then the results of the equation are those plotted in the following graph. The graph shows that electricity cost rises and gas costs falls as the absorptivity increases. The total cost increases because the change in heating (gas) cost is much less than the change in cooling (electricity) cost.

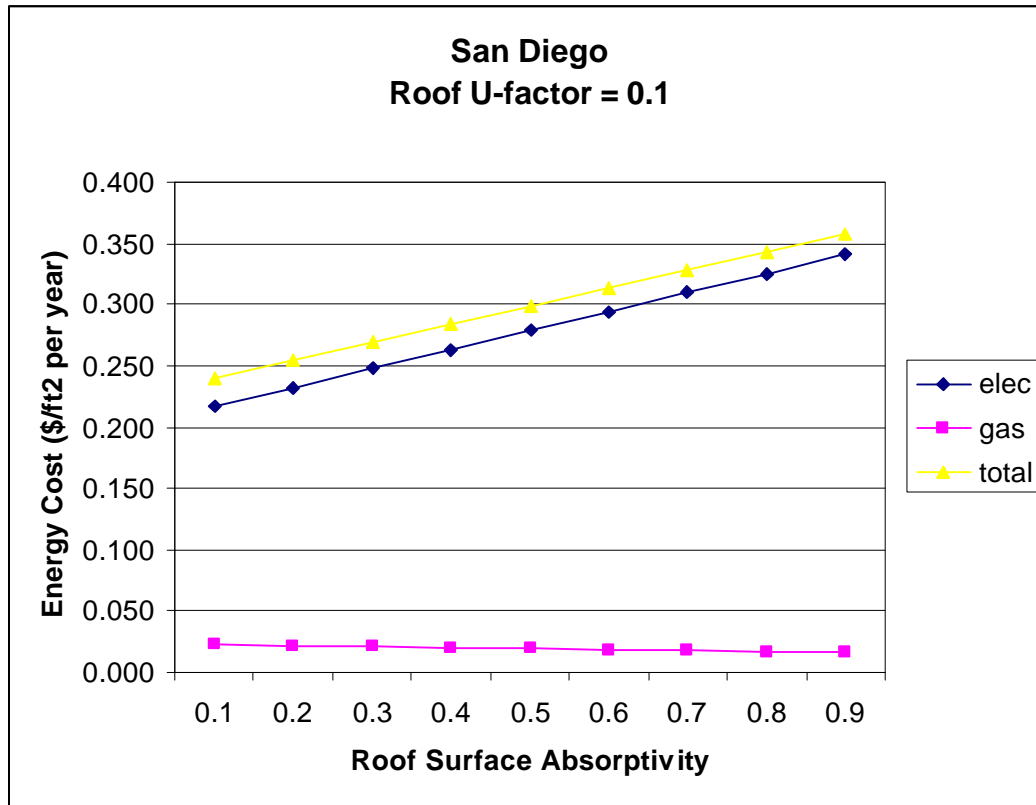


Figure 6 – Regression Equation Results for San Diego

Equal Energy Cost Multipliers

Using the regression equations, the U-factor that provides equal energy cost can be calculated. The equation reduces to:

$$\frac{U_1}{U_2} = \frac{C_2 + C_3 a_2}{C_2 + C_3 a_1}$$

Note that the C_1 coefficient is small compared to C_2 and C_3 . Therefore the $C_1 a$ term in the regression equation was eliminated because it has a small impact on results.

As an example of the results, the ratio for San Diego is 0.57 for residential and 0.61 for nonresidential coefficients when a_1 is 0.70 and a_2 is 0.45. Therefore, if the base case U-factor (U_1) were 0.092 (per Title 24), then the U-factor (U_2) for equal energy cost would be 0.161 for residential and 0.151 for non residential. Therefore, significantly less insulation would be required for equal energy cost with a cool roof.

Optimal U-factor Calculation

Rather than use the equal energy cost tradeoff result described in the previous section, the ASHRAE method takes another step to estimate the optimal insulation level under the cool roof. The optimal U-factor represents the level of insulation that is most cost effective when a cool roof exists. The end result of some algebra is that the optimum U-factor ratio is:

$$\frac{U_{opt,1}}{U_{opt,2}} = \left(\frac{U_{opt,1}}{U_2} \right)^{\frac{1}{2}}$$

(See [Akbari] for details)

This means that the ratio between the optimal cool roof U-factor ($U_{2, \text{opt}}$) and the optimal standard roof U-factor ($U_{1, \text{opt}}$) is equal to the square root of the ratio between the equal energy cost U-factors. For example, the equal energy cost multipliers are 0.57 and 0.61, so the corresponding optimal U-factor multipliers are 0.75 and 0.78. In this case, if the base case U-factor is 0.092, then the optimal U-factor with a cool roof is 0.123 for residential and 0.118 for nonresidential.

Simplification of Results for Standard Implementation

Finally, based on inspection of the U-factor multipliers for 20 climates, the ASHRAE committee created five climate categories and selected average multipliers for each. The result is the multipliers listed above in Table 5.3.1.1B of the Standard which is repeated on page 13.

ASHRAE Method Applied to California

The following table shows how the ASHRAE cool roof credit would affect Title 24 U-factor requirements. The optimal life-cycle cost multipliers are those from Standard 90.1 and are applied to the five California climate groupings based on mapping shown in an earlier section. The equal energy cost multipliers are equal to the square of the life-cycle cost multiplier.

Table 10 – Illustration of Equal Energy Cost and Optimal U-factors for Cool Roofs Applied to Title 24 Nonresidential Roof Requirements

	California Climate Zone				
	1, 16	2-5	6-10	11-13	14,15
U-factor (Title 24)	0.057	0.057	0.078	0.057	0.057
Equal Energy Cost Multiplier	1.0	0.72	0.69	0.74	0.69
Optimal Life-Cycle Cost Multiplier	1.0	0.85	0.83	0.86	0.83
Equal Energy Cost U-factor	0.057	0.079	0.113	0.077	0.083
Optimal Life-Cycle Cost U-factor	0.057	0.067	0.094	0.066	0.069

Preliminary Recommendation

The basis for the ASHRAE tradeoff is energy cost. However, California's energy standards use source energy as a tradeoff currency. Considering source energy, the relative value of gas will drop and cooling will become more important than in the Standard 90.1 tradeoff. On a per Btu basis and using national average prices, electricity is more than four times greater than gas, while source energy values it as three times greater. In addition, the ASHRAE multipliers are based on the optimal level of insulation under a cool roof rather than an equal energy tradeoff. The result is less credit for cool roofs using the ASHRAE method than would result from an equal energy tradeoff.

There are three straightforward elements to cool roof implementation in Title 24: prescriptive U-factor requirements, envelope tradeoff equations, and Alternative Compliance Methods. It is possible to choose all three or any combination. The recommendation is that all three be implemented.

- Use a method similar to ASHRAE that results in a less stringent U-factor requirement for cool roofs except use an equal source energy tradeoff and use new coefficients calculated for California. Add a row to the prescriptive roof U-factor requirements for qualifying cool roofs.
- Modify the envelope heat gain and heat loss tradeoff equations to include roof surface absorptivity as a factor. This would allow tradeoffs between roof performance and wall and window performance.
- Modify the ACM calculation rules to allow changes in roof absorptivity between the standard and proposed simulation models. This approach allows tradeoffs between roof performance and all other end uses.

It may also be desirable to set a minimum mandatory insulation requirement for nonresidential buildings so that roof insulation is not completely eliminated through one of the tradeoff methods.

An important issue to consider is whether cool roofs receive a credit (as in all existing examples) or become the basis for the Standard. In either case, another question is whether the life-cycle cost calculations used to set the current requirements should be redone. Probably the simplest path is to keep the existing insulation requirements and add a credit for cool roofs. Otherwise, if a cool roof becomes the basis for the standard then the life-cycle cost analysis should be updated. The result could be a decrease in the current R-value requirements with a second set of more stringent requirements for standard roof surfaces. The standard roof requirement could be based on equal source energy or on a separate life-cycle cost calculation.

Another important issue is that the calculations used to calculate credits for Cool Roofs typically underestimate their benefits. Most analyses use DOE2.1E. Studies done on residential buildings and schools in California using DOE2.1E show a large discrepancy (as much as twofold) between measured and simulated savings (Akbari et al., 1997 and Parker, 1998). There are several likely reasons for the underestimation. First, DOE2 does not explicitly model radiant heat transfer from the underside of the roof to the ceiling. This radiant transfer can be a big factor with the roof is dark. The second factor is that insulation R-factors typically degrade about 20% as insulation warms up to normal levels seen under hot roofing (Levinson 1996). DOE2 does not account for this temperature impact.

Preliminary Approach

- Use ASHRAE Standard 90.2 qualifying criteria for cool roof performance. As described earlier, these include two options, either reflectance and absorptivity or solar reflectance index.

To calculate the prescriptive U-factors

- Calculate a set of regression coefficients for each of the 16 California climate zones similar to those described for the ASHRAE 90.1 method described above. The equation will provide total source energy for cooling and heating. The DOE2.1E model will also be similar to the ASHRAE Standard 90.1 model except that other envelope constructions and internal gain assumptions will be set to match Title 24 prescriptive criteria. Two sets of schedules will be used: nonresidential and residential.

The form of the equation is:

$$E_i = C_0 + C_1a + C_2U + C_3Ua$$

Where:

E_i = annual source Btu for heating and cooling,

a = roof absorptivity,

U = roof U-factor,

C_0, C_1, C_2, C_3 = regression coefficients.

- Using the regression equations, calculate the equal source energy U-factor for cool roofs. Use the 90.1 method described earlier except use source energy as the metric.

$$\frac{U_1}{U_2} = \frac{C_2 + C_3a_2}{C_2 + C_3a_1}$$

Set a_1 to 0.7, which is the absorptivity used in the life-cycle analysis for the current standards. Set a_2 to 0.45, which is the value used in the ASHRAE analysis to represent an aged reflective roof.

U_1 is the current U-factor requirement and U_2 would be the required U-factor for qualifying cool roofs.

- Add a line to Tables 1-H and 1-I with a different U-factor for qualifying cool roofs. Consider adding a corresponding insulation R-value that would also be acceptable for compliance.

To update the tradeoff equations:

- Add a term to the heat gain equation to account for roof surface absorptivity. The new term would likely take the form:

$$A \times U \times \alpha \times \text{RSF}$$

where

A = roof area

U = roof U-factor

α = roof absorptivity (either 0.7 for 0.45 for cool roof)

RSF = Roof Solar Factor, which depends on climate zone and roof mass.

The RSF term will need to be calculated. The simulation results used for the regression equations described above can also be used to calculate RSF for each climate zone.

Finally, to modify ACM procedures, rules for roof absorptivity on the standard building and proposed building models need to be added to the ACM Manual. The recommended approach is to assume an absorptivity of 0.7 for the standard building and 0.45 for the proposed building if a qualifying cool roof is specified. Emissivity would be constant between the proposed design and the budget building.

HVAC Equipment Efficiency Tables

Both ASHRAE 1999 and California 1998 specify minimum efficiency for HVAC equipment. The equipment efficiency requirements in ASHRAE 1998 are more recent and were developed in cooperation with equipment manufacturers and trade organizations. For the most part, they are more stringent than California 1998 and should be considered as a potential upgrade.

Comparison of California 1998 and ASHRAE 1999

The ASHRAE 1999 Requirements exceed the efficiency requirements of California's 1999 Standard in all but the following areas⁵:

- Reciprocating chillers greater than 300 with ozone depleting factors greater than R-22,
- Air-cooled chillers without condensers, and
- Gas- and oil-fired warm-air furnaces.

The efficiency tables are summarized in Tables 6.2.1 A through J of ASHRAE/IESNA Standard 90.1-1999. Many of the tables have two minimum efficiency levels, one, which is in effect, and another, which is scheduled to take effect October 29, 2001. The later level of efficiency is recommended for the California nonresidential energy efficiency standards since the effective date will be in 2002.

ASHRAE 1999 also covers more types of equipment. The following products are addressed by ASHRAE 1999, but not California 1998:

- Absorption chillers
- Heat rejection equipment (cooling towers, air-cooled condensers and evaporative condensers)
- Hot-water supply boilers.

ASHRAE 1999 also addresses water-cooled centrifugal chillers that are designed for operation at conditions other than the ARI testing points. This is done through equivalency tables that are provided for different conditions of evaporator flow, condenser flow, evaporator leaving water temperature and condenser entering

⁵ In addition, the reference standards used in ASHRAE 1999 are more up to date than those in the California 1998.

water temperature. Exceptions to the efficiency requirements are made for chillers designed for low temperature operation⁶.

Life-Cycle Cost

For ASHRAE 1999, equipment manufacturers and their trade organizations (ARI and GAMA) participated in a detailed life cycle cost study to determine the most cost effective level of efficiency for various classes of equipment. Energy use was calculated using full-load equivalent operating hours (FLEOH) for 11 climates. The FLEOH represents the number of hours the equipment must operate at rated capacity (full load) to provide the actual cooling energy. It is calculated by dividing the annual cooling load by the rated efficiency of the equipment. Annual electric energy use is given by the following equation.

$$\text{AnnualEnergyUse} = \frac{\text{FLEOH} \times \text{RatedCapacity}}{\text{EER}/3.413}$$

A methodology was used where each incremental increase in efficiency must be cost justified against the previous level of efficiency. An incremental change in efficiency was considered to be cost effective if the annual energy cost savings time the scalar ratio of 8.0 were greater than the incremental first cost of increasing the efficiency.

The cost for increased efficiency was determined from cost curves provided by ARI. The cost curves represent the incremental increase in first cost as a function of incremental improvements in full- and part-load equipment efficiencies.

Figure 7 – Example Cost Mechanical Equipment Cost Curve

As noted earlier, ASHRAE 1999 valued a kWh of energy savings at \$0.64 while the 1992 California methodology valued a kWh of savings at \$1.04. Everything else being equal, the ASHRAE 1999 requirements are cost effective in California.

Preliminary Recommendation

We propose to adopt the more stringent ASHRAE 1999 tables (10/29/2001 column data) with the more current references to rating conditions. No additional life-cycle cost analysis is proposed due the daunting task of developing the cost curves. This is not really a good reason because we could use the ARI cost curves but use different base case data. Would we need ARI's permission to use the data. This may be a more serious issue. ASHRAE's thorough life-cycle cost analysis using less stringent energy cost criteria will easily pass California's cost criteria.

Air-Side Economizers

Air-side economizers are an important energy conservation strategy in most California climates. The main issue with economizers is the persistence of savings, especially for small systems. Field experience has shown that air-side economizer controls often fail to operate properly if they are not carefully maintained and regularly tested. Field studies by the National Laboratories and the utilities have estimated that between 40% and 70% of all controls on packaged units are malfunctioning.

Comparison of California 1998 and ASHRAE 1999

There are three main differences in the way that air-side economizers are addressed between ASHRAE 1999 and California 1998.

⁶ The off-design water-cooled chiller equivalency tables were not developed through a rigorous life cycle cost analysis. They were developed using the cost effective breakpoints from the ARI rated test points and adjusted for equivalent equipment operating at other operating conditions.

Prescriptive Trade-Off Against Equipment Efficiency

ASHRAE 1999 offers a trade-off between HVAC efficiency and the air-side economizer requirement, e.g. the economizer requirement is waived if the EER is high enough. The trade-off is based on a thorough study of equivalent energy use between high-efficiency systems and economizers. The required margin depends on system size and cooling degree days (see Table 6.1.3 of ASHRAE/IESNA Standard 90.1-1999, reproduced below). California only provides this trade-off through the whole-building performance method of compliance, which is rarely applied to the smaller projects where packaged rooftop equipment is commonly applied.

Table 12 – Economizer Trade-off Table from ASHRAE

Table 6.1.3 (I-P Units)

Eliminate Required Economizer by Increasing Cooling Efficiency

Unitary Systems with Heat Pump Heating						
System Size (kBtu/h)	Mandatory Minimum EER	Cooling Degree-Days (CDD50)				
		0 - 3600	3601 - 5400	5401 - 7200	7201 - 9000	9001 - 10800
		Minimum Cooling Efficiency Required (EER) ^a				
≥ 65 and < 135	10.1	N/A ^b	12.1	11.6	11.1	10.7
≥ 135 and ≤ 240	9.3	N/A ^b	11.3	10.8	10.4	9.9
> 240 and < 760	9.0	N/A ^b	10.9	10.5	10.0	9.6
Other Unitary Systems						
System Size (kBtu/h)	Mandatory Minimum EER	Cooling Degree-Days (CDD50)				
		0 – 3600	3601 - 5400	5401 - 7200	7201 - 9000	9001 - 10800
		Minimum Cooling Efficiency Required (EER) ^a				
≥ 65 and < 135	10.3	N/A ^b	12.5	12.0	11.5	11.0
≥ 135 and ≤ 240	9.7	N/A ^b	11.5	11.1	10.6	10.1
> 240 and < 760	9.5	N/A ^b	11.2	10.7	10.3	9.9
^a Each EER shown below should be reduced by 0.2 for units with a heating section other than electric resistance heat.						
^b Elimination of required economizer is not allowed.						

Controls

ASHRAE 1999 introduced restrictions on the type of controls that may be used to shut down economizer operation when outdoor are too warm or moist. These restrictions are shown in the table below. In mild climates, the type of control is largely unimportant to energy efficiency. However, drybulb temperature-based controllers are less likely to fail in the field compared to enthalpy-based controllers, largely due to drift and calibration problems with the latter. In humid climates, however, enthalpy-based controllers will limit the unintended introduction of latent load from cool humid air. Differential drybulb temperature based economizers in these climates can actually increase the system's energy usage over a fixed drybulb or enthalpy economizers. High Limit. ASHRAE largely followed California's code requirements for air-side economizers with the exception of this new requirement which limits the type of high-limit control based on climate.

Table 13 – Economizer Control Restrictions from ASHRAE

Table 6.3.1.1.3A (I-P Units)

High Limit Shutoff Control Options for Air Economizers

Climate	Allowed Control Types	Prohibited Control Types
Dry $T_{wb} < 69^{\circ}\text{F}$ or ($T_{wb} < 75^{\circ}\text{F}$ and $T_{db} \geq 100^{\circ}\text{F}$) ^a	Fixed Dry Bulb Differential Dry Bulb Electronic Enthalpy ^b Differential Enthalpy	Fixed Enthalpy
Intermediate $69^{\circ}\text{F} \leq T_{wb} \leq 73^{\circ}\text{F}$ $T_{db} < 100^{\circ}\text{F}$	Fixed Dry Bulb Differential Dry Bulb Fixed Enthalpy Electronic Enthalpy ^b Differential Enthalpy	None
Humid $T_{wb} > 73^{\circ}\text{F}$	Fixed Dry Bulb Fixed Enthalpy Electronic Enthalpy ^b Differential Enthalpy	Differential Dry Bulb
^a T_{wb} is the 1% cooling design wet-bulb temperature. T_{db} is the 1% cooling design dry-bulb temperature. ^b Electronic enthalpy controllers are devices that use a combination of humidity and dry-bulb temperature in their switching algorithm		

Table 14 – Economizer Control Settings from ASHRAE

Table 6.3.1.1.3B (I-P Units)

High Limit Shutoff Control Settings for Air Economizers

Device Type	Climate	Required High Limit (Economizer Off When):	
		Equation	Description
Fixed Dry Bulb	Dry	$T_{OA} > 75^{\circ}\text{F}$	Outside air temperature exceeds 75°F
	Intermediate	$T_{OA} > 70^{\circ}\text{F}$	Outside air temperature exceeds 70°F
	Humid	$T_{OA} > 65^{\circ}\text{F}$	Outside air temperature exceeds 65°F
Differential Dry Bulb	All	$T_{OA} > T_{RA}$	Outside air temperature exceeds return air temperature
Fixed Enthalpy	All	$h_{OA} > 28 \text{ Btu/lb}^b$	Outside air enthalpy exceeds 28 Btu/lb of dry air ^b
Electronic Enthalpy	All	$(T_{OA}, RH_{OA}) > A$	Outside air temperature/RH exceeds the "A" set-point curve ^a
Differential Enthalpy	All	$h_{OA} > h_{RA}$	Outside air enthalpy exceeds return air enthalpy
^a Set point "A" corresponds to a curve on the psychrometric chart that goes through a point at approximately 75°F and 40% relative humidity and is nearly parallel to dry bulb lines at low humidity levels and nearly parallel to enthalpy lines at high humidity levels. ^b At altitudes substantially different than sea level, the Fixed Enthalpy limit value shall be set to the enthalpy value at 75°F and 50% relative humidity. As an example, at approximately 6000 ft elevation the fixed enthalpy limit is approximately 30.7 Btu/lb.			

Size Exceptions

California 1998 and previous versions of Standard 90.1 exempt small air conditioning equipment from the economizer requirement. Economizers are not cost effective for small equipment since cost does not go down in direction proportion to equipment size as do energy savings. Moreover, the quality of small economizers is generally poor (to keep costs down) and maintenance of small equipment is seldom up to the same standards as larger equipment. The result is that economizers often fail. Should they fail in a position that allows more than minimum ventilation air into the building, the added energy cost will be higher than if the economizer were never used. If the economizer fails with the outdoor air damper closed below minimum ventilation requirements, poor indoor air quality may result. Therefore, it is important to be sure that the minimum size exception is determined in a rational manner. The table below summarizes the size exceptions from ASHRAE 1999.

Table 15 – Economizer Size Exception from ASHRAE

Table 6.3.1 (I-P Units)

Minimum System Size for Which an Economizer is Required

No. of Hours Between 8 am and 4 pm with 55°F < T _{db} < 69°F	1% Cooling Design Wet-Bulb Temperature		
	T _{wb} < 69°F	69°F ≤ T _{wb} ≤ 73°F	T _{wb} > 73°F
	Minimum System Size (Btu/h)	Minimum System Size (Btu/h)	Minimum System Size (Btu/h)
0-199	N.R.	N.R.	N.R.
200-399	135,000	N.R.	N.R.
400-599	135,000	N.R.	N.R.
600-799	65,000	135,000	N.R.
800-999	65,000	135,000	135,000
1000-1199	65,000	65,000	135,000
>1199	65,000	65,000	65,000
N.R. means that there is no system size for which an economizer is a requirement in this climate.			

Life-Cycle Cost

- **Trade-off Table.** ASHRAE studied the trade-off in energy usage between packaged equipment at higher efficiencies without economizers and minimally complying equipment with perfectly functioning air-side economizers. The efficiencies applied to the trade-off method are the break-even efficiencies.
- **Controls.** ASHRAE and PNNL performed a thorough life-cycle cost analysis of economizer performance in a variety of climates. Based on this study, a new requirement for high-limit controls based on climate type was introduced.
- **Size Exception.** ASHRAE and PNNL performed a thorough life-cycle cost analysis of economizer performance in a variety of climates and assuming realistic first costs and maintenance costs for economizers. Regressions were done to determine which climate variables correlated to economizer effectiveness, resulting in Table 6.3.1 (reprinted below). Title 24-98 requires economizers for AC units with capacities exceeding both 75,000 Btu/hour and 2,500 cfm. For ASHRAE 1999, there is no airflow rate criterion and the cooling capacity limit varies by climate. For mild climates, the limit is lower (more stringent) than Title 24. For warmer, more humid climates, the limit will be higher (less stringent) than Title 24.

Preliminary Recommendations

- **Trade-Off Table.** The ASHRAE 1999 trade-off tables should be adopted for California to add added flexibility in meeting the requirements of the standard. Although this measure was evaluated to provide a zero-sum energy tradeoff between fully functioning air-side economizer and high efficiency packaged HVAC units, it is likely to save energy in the net as unit efficiency has greater persistence than economizer operation.
- **Controls.** Tables 6.3.1.1.3 A and B from ASHRAE 1999 should be modified for California. The temperature ranges should be mapped explicitly to California climate zones.
- **Size Exception.** A simplified version of ASHRAE's table 6.3.1 is recommended for California. Each cell of the table will be mapped to California's climate zones. The final table will have two columns, the first listing climate zone and the second listing the minimum system size.

Heat-Rejection Equipment Fan Controls

Heat rejection equipment, including cooling towers and condensers represent opportunities for energy savings that have not previously been addressed by energy efficiency standards.

Comparison of California 1998 and ASHRAE 1999

ASHRAE 1999 provides minimum fan control for heat-rejection equipment (cooling towers, evaporative condensers and air-cooled condensers). Packaged equipment that is covered by the equipment efficiency standards is exempted. California 1998 has no similar requirement. The measure reads as follows:

"Each fan powered by a motor of 7.5 hp or larger shall have the capability to operate that fan at two-thirds of full speed or less and shall have controls that automatically change the fan speed to control the leaving fluid temperature or condensing temperature/pressure of the heat rejection device."

Life-Cycle Cost

This measure was support by a detailed life-cycle cost study co-sponsored by the ASHRAE SSPC 90.1 committee and the ASHRAE Technical Committee 8.6 (cooling towers and evaporative condensers). The results of the study indicated that 2-speed controls were cost effective down to 5hp using the ASHRAE criteria. A draft paper detailing the methodology and results is in peer review for a future ASHRAE TC8.6 forum. The measure went through three rounds of public review.

Preliminary Recommendation

This measure is proposed as a new prescriptive requirement.

Performance Testing and Completion Requirements

Real energy efficiency requires that building systems and components be carefully inspected, evaluated and tested during and following construction. Controls and other devices must be calibrated. When these activities are carried out in a methodical and thorough manner, the process is called building commissioning. Most building professionals are learning that commissioning is critical to the effective performance of buildings. Energy codes address the design of buildings, not their operation. Since, commissioning is a transition activity between construction and operation, it has been addressed in codes in a very limited way.

Comparison of California 1998 and ASHRAE 1999

California 1998 has few requirements related to performance testing and completion. These are in §10-103, subparagraph (b), and only deal with operation and maintenance manuals to be provided to the owner by the builder. This language follows:

From California 1998, §10-103*(b) Operating and Maintenance Information to be Provided by Builder.*

1. *Operating information.* The builder shall provide the building owner at occupancy the appropriate Certificate(s) of Compliance and a list of the features, materials, components, and mechanical devices installed in the building and instructions on how to operate them efficiently. The instructions shall be consistent with specifications set forth by the executive director.

For residential buildings, such information shall, at a minimum, include information indicated on forms Certificate of Compliance (CF-1R), Mandatory Measures (MF-1R), Installation Certificate (CF-6R), Insulation Certificate (IC-1), and a manual which provides all information specified in this Section 10-103 (b). The Home Energy Manual (P400-92-031, July 1992) may be used to meet the requirement for providing this manual.

For nonresidential buildings, such information shall, at a minimum, include information required by the Certificates of Compliance, forms ENV-1, MECH-1 and LTG-1, an Installation Certificate and an Insulation Certificate. For dwelling units, buildings or tenant spaces which are not individually owned and operated, or are centrally operated, such information shall be provided to the person(s) responsible for operating the feature, material, component, or mechanical device installed in the building.

2. *Maintenance information.* The builder shall provide to the building owner at occupancy maintenance information for all features, materials, components, and manufactured devices that require routine maintenance for efficient operation. Required routine maintenance actions shall be clearly stated and incorporated on a readily accessible label. The label may be limited to identifying, by title and/or publication number, the operation and maintenance manual for that particular model and type of feature, material, component, or manufactured device.

For dwelling units, buildings or tenant spaces which are not individually owned and operated, or are centrally operated, such information shall be provided to the person(s) responsible for maintaining the feature, material, component, or mechanical device installed in the building.

3. *Ventilation information.* For nonresidential buildings, the builder shall provide the building owner at occupancy a description of the quantities of outdoor and recirculated air that the ventilation systems are designed to provide to each area. For buildings or tenant spaces which are not individually owned and operated, or are centrally operated, such information shall be provided to the person(s) responsible for operating and maintaining the feature, material, component, or mechanical device installed in the building.

From California 1998, §121 (f)

(f) Completion and Balancing. Before an occupancy permit is granted for a new building or space, or a new space-conditioning or ventilating system serving a building or space is operated for normal use, all ventilation systems serving the building or space shall be documented in accordance with Title 8, Section 5142 (b) of the California Safety Code (1987) to be providing the minimum ventilation rate specified in Section 121 (b) 2, as determined using one of the following procedures:

1. Balancing. The system shall be balanced in accordance with the National Environmental Balancing Bureau (NEBB) Procedural Standards (1983) or Associated Air Balance Council (AABC) National Standards (1989); or

2. Outside air certification. The system shall provide the minimum outside air as shown on the mechanical drawings, and shall be measured by the installing licensed C-20 mechanical contractor

and certified by (1) the design mechanical engineer, (2) the installing licensed C-20 mechanical contractor, or (3) the person with overall responsibility for the design of the ventilation system; or

3. Outside air measurement. The system shall be equipped with a calibrated local or remote device capable of measuring the quantity of outside air on a continuous basis and displaying that quantity on a readily accessible display device; or 4. Another method approved by the commission.

The language in ASHRAE 1999 is a little more explicit about the content of manuals to be provided to owners. ASHRAE 1999 also requires a commissioning plan for projects larger than 50,000 ft². This language follows:

From ASHRAE 1999

6.2.5 Completion Requirements

6.2.5.1 Drawings. Construction documents shall require that within 90 days after the date of system acceptance, record drawings of the actual installation be provided to the building owner. Record drawings shall include as a minimum the location and performance data on each piece of equipment, general configuration of duct and pipe distribution system including sizes, and the terminal air or water design flow rates.

6.2.5.2 Manuals. Construction documents shall require that an operating manual and a maintenance manual be provided to the building owner within 90 days after the date of system acceptance. These manuals shall be in accordance with industry accepted standards (see Appendix E) and shall include, at a minimum, the following:

(a) Submittal data stating equipment size and selected options for each piece of equipment requiring maintenance.

(b) Operation manuals and maintenance manuals for each piece of equipment requiring maintenance, except equipment not furnished as part of the project. Required routine maintenance actions shall be clearly identified.

(c) Names and addresses of at least one service agency.

(d) HVAC controls system maintenance and calibration information, including wiring diagrams, schematics, and control sequence descriptions. Desired or field determined set points shall be permanently recorded on control drawings at control devices, or, for digital control systems, in programming comments.

(e) A complete narrative of how each system is intended to operate, including suggested set points.

6.2.5.3 System Balancing

6.2.5.3.1 General. Construction documents shall require that all HVAC systems be balanced in accordance with generally accepted engineering standards (see Appendix E). Ducted air and water flow rates shall be measured and adjusted to deliver final flow rates within 10% of design rates.

Exception to 6.2.5.3.1: Variable speed, variable volume flow distribution systems need not be balanced upstream of an pressure independent device.

Construction documents shall require a written balance report be provided to the owner for HVAC systems serving zones with a total conditioned area exceeding 5000 ft² (460 m²).

6.2.5.3.2 Air System Balancing. Air systems shall be balanced in a manner to first minimize throttling losses. Then, for fans with system power of greater than 1 hp (0.75 kW), fan speed shall be adjusted to meet design flow conditions, except variable flow distribution systems need not be balanced upstream of the controlling device (e.g., a calibrated VAV box).

6.2.5.3.3 Hydronic System Balancing. Hydronic systems shall be proportionately balanced in a manner to first minimize throttling losses, then the pump impeller shall be trimmed or pump speed shall be adjusted to meet design flow conditions. Each hydronic system shall have either the ability to measure differential pressure increase across the pump, or test ports at each side of each pump.

Exceptions to 6.2.5.3.3:

- (a) Pumps with pump motors of 10 hp (7.5 kW) or less.
- (b) When throttling results in no greater than 5% of the nameplate horsepower draw, or 3 hp, whichever is greater, above that required if the impeller was trimmed.

6.2.5.4 System Commissioning. HVAC control systems shall be tested to assure that control elements are calibrated, adjusted, and in proper working condition.

For projects larger than 50,000 ft² (4600 m²) conditioned area except warehouses and semiheated spaces, detailed instructions for commissioning HVAC systems (see Appendix E) shall be provided by the designer in plans and specifications.

Discussion

Commissioning is critical to the energy performance of buildings. The question is whether and to what extent the energy efficiency standards should be used to promote or require commissioning. Other states are attempting to use the code. The City of Seattle has adopted the ASHRAE 1999 language with a few modifications. This is not being promoted as a modification to the Washington state code. Massachusetts has also adopted much of the ASHRAE 1999 language, but added to it to require that design professionals “certify” (1) that construction was completed in accordance with plans and specifications and (2) that the as-built drawings are reasonably accurate. In addition, the building owner or developer must confirm that they have received the required controls documentation, operation manuals and maintenance manuals.

Preliminary Recommendation

No recommendation is provided at this time as whether or to what extent commissioning should be included in the Energy Standards. Workshop participants are encouraged to present their views.

Simplified HVAC System Approach

According to the USDOE Commercial Building Energy Consumption (CBEC) data, approximately 80% of the buildings in the United States are heated and cooled by single-zone package HVAC equipment. The prevalence of relatively simple buildings with simple systems led Washington State and ASHRAE to introduce an easy method of compliance for qualifying “simple” systems.

Comparison of California 1998 and ASHRAE 1999

With ASHRAE 1999, one and two story non-residential buildings served by air-cooled packaged HVAC equipment have a single sheet of mechanical requirements. With California 1998, designers must sift through multiple pages of requirements to find the ones that apply for these same buildings and systems. The bulk of the requirements in the HVAC section are not appropriate for simple systems, e.g. the zone isolation or fan-power requirements. A streamlined approach of compliance could facilitate the process of compliance for a majority of new construction.

Preliminary Recommendation

It is recommended that California adopt a similar simple path of compliance for simple HVAC systems, but that this change be implemented not through changes to the standard, but rather through the nonresidential manual. This recommendation does not include changing the requirements for simple systems, but rather to present those requirements in the nonresidential manual in a simplified manner similar to ASHRAE 1999.

Appendix A – ASHRAE Building Envelope Criteria for California

Table 16 – Nonresidential Fenestration Criteria – ASHRAE 1999

	Bin 5	Bin 6	Bin 7	Bin 8	Bin 9	Bin 11	Bin 12	Bin 14	Bin 15
Roof, Insulation Entirely Above Deck	0.0634	0.0634	0.0928	0.0634	0.0634	0.0634	0.0928	0.0634	0.0634
Roof, Metal Building	0.065	0.065	0.072	0.065	0.065	0.065	0.065	0.065	0.065
Roof, Attic and Other	0.0339	0.0339	0.0339	0.0339	0.0339	0.0339	0.0339	0.0339	0.0339
Wall, Mass	0.58	0.58	0.58	0.58	0.58	0.151	0.151	0.151	0.151
Wall, Metal Building	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113
Wall, Steel Framed	0.1242	0.1242	0.1242	0.1242	0.1242	0.1242	0.1242	0.1242	0.1242
Wall, Wood Framed and Other	0.0887	0.0887	0.0887	0.0887	0.0887	0.0887	0.0887	0.0887	0.0887
Below Grade Walls	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14
Floor, Mass	0.1374	0.1374	0.1374	0.1374	0.1374	0.1067	0.1374	0.1067	0.1067
Floor, Steel Joist	0.0521	0.0521	0.0521	0.0521	0.0521	0.0521	0.0521	0.0521	0.0521
Floor, Wood Framed and Other	0.0508	0.0508	0.0663	0.0508	0.0508	0.0508	0.0508	0.0508	0.0508
Slab-on-Grade, Unheated	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
Slab-on-Grade, heated	1.02	1.02	1.02	1.02	1.02	1.02	1.02	0.95	0.95
Opaque Doors, Swinging	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Opaque Doors, Non-Swinging	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45
Window U-factor, Fixed	1.22	1.22	1.22	1.22	1.22	0.57	1.22	0.57	0.57
Window U-factor, Fixed50	1.22	1.22	1.22	1.22	0.45	0.56	0.56	0.46	0.45
Window U-factor, Operable	1.27	1.27	1.27	1.27	1.27	0.67	1.27	0.67	0.67
Window U-factor, Operable50	1.27	1.27	1.27	1.27	0.47	0.67	0.67	0.47	0.47
Skylight U-factor, Glass Curb	1.98	1.98	1.98	1.98	1.98	1.17	1.98	1.17	1.17
Skylight U-factor, Glass Curb 10	0	0	0	0	0	0	0	0	0
Skylight U-factor, Glass No Curb	1.36	1.36	1.36	1.36	1.36	0.68	1.36	0.68	0.68
Skylight U-factor, Glass No Curb 10	0	0	0	0	0	0	0	0	0
Skylight U-factor, Plastic	0.93	0.93	1.29	0.93	1.1	1.1	1.29	0.93	0.93
Skylight U-factor, Plastic 10	0	0	0	0	0	0	0	0	0
Window SHGC, 10 WWR	0.25	0.39	0.61	0.39	0.61	0.39	0.61	0.49	0.49
Window SHGC, 20 WWR	0.25	0.25	0.61	0.25	0.39	0.39	0.61	0.39	0.49
Window SHGC, 30 WWR	0.25	0.25	0.44	0.25	0.39	0.39	0.61	0.39	0.49
Window SHGC, 40 WWR	0.25	0.25	0.44	0.25	0.34	0.39	0.39	0.39	0.49
Window SHGC, 50 WWR Fixed	0.17	0.17	0.31	0.15	0.2	0.27	0.09	0.26	0.39
Window SHGC, 50 WWR Operable	0.17	0.16	0.31	0.14	0.19	0.26	0.39	0.36	0.36
Window SHGC North, 10 WWR	0.61	0.61	0.82	0.61	0.82	0.49	0.82	0.49	0.49
Window SHGC North, 20 WWR	0.61	0.61	0.61	0.61	0.61	0.49	0.82	0.49	0.49
Window SHGC North, 30 WWR	0.61	0.61	0.61	0.61	0.61	0.49	0.61	0.49	0.49
Window SHGC North, 40 WWR	0.61	0.61	0.61	0.61	0.61	0.39	0.61	0.49	0.49
Window SHGC North, 50 WWR Fixed	0.44	0.42	0.39	0.38	0.3	0.32	0.09	0.36	0.72
Window SHGC North, 50 WWR Operable	0.44	0.42	0.38	0.37	0.26	0.36	0.61	0.43	0.49

Table 17 – Residential Fenestration Criteria – ASHRAE 1999

	Bin 5	Bin 6	Bin 7	Bin 8	Bin 9	Bin 11	Bin 12	Bin 14	Bin 15
Roof, Insulation Entirely Above Deck	0.0634	0.0634	0.0634	0.0634	0.0634	0.0634	0.0634	0.0634	0.0634
Roof, Metal Building	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
Roof, Attic and Other	0.0269	0.0339	0.0339	0.0269	0.0339	0.0339	0.0339	0.0339	0.0339
Wall, Mass	0.151	0.151	0.151	0.1234	0.151	0.1234	0.1234	0.1043	0.1234
Wall, Metal Building	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113
Wall, Steel Framed	0.1242	0.1242	0.1242	0.0844	0.1242	0.0844	0.1242	0.0844	0.0844
Wall, Wood Framed and Other	0.0887	0.0887	0.0887	0.0887	0.0887	0.0887	0.0887	0.0887	0.0887
Below Grade Walls	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14
Floor, Mass	0.1067	0.1067	0.1374	0.1067	0.1067	0.0873	0.1067	0.0873	0.0873
Floor, Steel Joist	0.0521	0.0521	0.0521	0.0521	0.0521	0.0521	0.0521	0.0521	0.0521
Floor, Wood Framed and Other	0.0508	0.0508	0.0508	0.0508	0.0508	0.0331	0.0508	0.0331	0.0331
Slab-on-Grade, Unheated	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
Slab-on-Grade, heated	1.02	1.02	1.02	1.02	1.02	0.95	0.95	0.84	0.84
Opaque Doors, Swinging	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Opaque Doors, Non-Swinging	1.45	1.45	1.45	1.45	1.45	1.45	1.45	0.5	1.45
Window U-factor, Fixed	1.22	1.22	1.22	1.22	1.22	0.57	1.22	0.57	0.57
Window U-factor, Fixed50	1.22	1.22	1.22	1.22	1.22	0.56	0.72	0.46	0.45
Window U-factor, Operable	1.27	1.27	1.27	1.27	1.27	0.67	1.27	0.67	0.67
Window U-factor, Operable50	1.27	1.27	1.27	1.27	1.27	0.67	0.81	0.47	0.51
Skylight U-factor, Glass Curb	1.98	1.98	1.98	1.98	1.98	0.98	1.17	1.17	1.31
Skylight U-factor, Glass Curb 10	0	0	0	0	0	0	0	0	0
Skylight U-factor, Glass No Curb	1.36	1.36	1.36	1.36	1.36	0.68	0.68	0.68	0.68
Skylight U-factor, Glass No Curb 10	0	0	0	0	0	0	0	0	0
Skylight U-factor, Plastic	0.93	0.93	0.93	0.93	0.93	0.74	0.91	0.91	1.12
Skylight U-factor, Plastic 10	0	0	0	0	0	0	0	0	0
Window SHGC, 10 WWR	0.39	0.61	0.61	0.39	0.61	0.39	0.61	0.49	0.72
Window SHGC, 20 WWR	0.25	0.44	0.61	0.39	0.61	0.39	0.61	0.39	0.72
Window SHGC, 30 WWR	0.25	0.44	0.61	0.25	0.39	0.39	0.61	0.39	0.51
Window SHGC, 40 WWR	0.25	0.40	0.44	0.25	0.34	0.39	0.61	0.39	0.51
Window SHGC, 50 WWR Fixed	0.17	0.29	0.31	0.14	0.19	0.26	0.33	0.26	0.39
Window SHGC, 50 WWR Operable	0.17	0.29	0.31	0.14	0.19	0.26	0.51	0.36	0.36
Window SHGC North, 10 WWR	0.61	0.61	0.82	0.61	0.82	0.49	0.82	0.49	0.72
Window SHGC North, 20 WWR	0.61	0.61	0.61	0.61	0.61	0.49	0.82	0.49	0.72
Window SHGC North, 30 WWR	0.61	0.61	0.61	0.61	0.61	0.49	0.82	0.49	0.72
Window SHGC North, 40 WWR	0.61	0.61	0.61	0.61	0.61	0.49	0.82	0.49	0.72

Criteria Format

Table 18 shows one of the 26 building envelope criteria tables from ASHRAE 1999. Criteria are given for three space categories: nonresidential, residential and semi-heated. The nonresidential and residential space categories are defined similarly to those used in California 1998. The semi-heated space category does not exist in California 1998 and applies to warehouses and other buildings that have small heating systems not generally capable of maintaining human comfort.

Table 18 – Sample Building Envelope Criteria Table from ASHRAE 1999

	NONRESIDENTIAL		RESIDENTIAL		SEMIHEATED	
OPAQUE ELEMENTS	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-value	Assembly Maximum	Insulation Min. R-Value
Roofs						
Insulation Entirely above Deck	U-0.063	R-15.0 ci	U-0.063	R-15.0 ci	U-0.218	R-3.8 ci
Metal Building	U-0.065	R-19.0	U-0.065	R-19.0	U-0.097	R-10.0
Attic and Other	U-0.034	R-30.0	U-0.027	R-38.0	U-0.081	R-13.0
Walls, Above-Grade						
Mass	U-0.151*	R-5.7 ci*	U-0.104	R-9.5 ci	U-0.580	NR
Metal Building	U-0.113	R-13.0	U-0.113	R-13.0	U-0.134	R-10.0
Steel Framed	U-0.124	R-13.0	U-0.064	R-13.0 + R-7.5 ci	U-0.124	R-13.0
Wood Framed and Other	U-0.089	R-13.0	U-0.089	R-13.0	U-0.089	R-13.0
Wall, Below-Grade						
Below-Grade Wall	C-1.140	NR	C-1.140	NR	C-1.140	NR
Floors						
Mass	U-0.107	R-6.3 ci	U-0.087	R-8.3 ci	U-0.322	NR
Steel Joist	U-0.052	R-19.0	U-0.038	R-30.0	U-0.069	R-13.0
Wood Framed and Other	U-0.051	R-19.0	U-0.033	R-30.0	U-0.066	R-13.0
Slab-On-Grade Floors						
Unheated	F-0.730	NR	F-0.730	NR	F-0.730	NR
Heated	F-0.950	R-7.5 for 24 in.	F-0.840	R-10.0 for 36 in.	F-1.020	R-7.5 for 12 in.
Opaque Doors						
Swinging	U-0.700		U-0.700		U-0.700	
Non-Swinging	U-1.450		U-0.500		U-1.450	
FENESTRATION	Assembly Max. U (Fixed/ Operable)	Assembly Max. SHGC (All Orientations/ North-Oriented)	Assembly Max. U (Fixed/ Operable)	Assembly Max. SHGC (All Orientations/ North-Oriented)	Assembly Max. U (Fixed/ Operable)	Assembly Max. SHGC (All Orientations/ North-Oriented)
Vertical Glazing, % of Wall						
0-10.0%	U _{fixed} -0.57 U _{oper} -0.67	SHGC _{all} - 0.39 SHGC _{north} - 0.49	U _{fixed} -0.57 U _{oper} -0.67	SHGC _{all} - 0.39 SHGC _{north} - 0.49	U _{fixed} -1.22 U _{oper} -1.27	SHGC _{all} - NR SHGC _{north} - NR
10.1-20.0%	U _{fixed} -0.57 U _{oper} -0.67	SHGC _{all} - 0.39 SHGC _{north} - 0.49	U _{fixed} -0.57 U _{oper} -0.67	SHGC _{all} - 0.39 SHGC _{north} - 0.49	U _{fixed} -1.22 U _{oper} -1.27	SHGC _{all} - NR SHGC _{north} - NR
20.1-30.0%	U _{fixed} -0.57 U _{oper} -0.67	SHGC _{all} - 0.39 SHGC _{north} - 0.49	U _{fixed} -0.57 U _{oper} -0.67	SHGC _{all} - 0.39 SHGC _{north} - 0.49	U _{fixed} -1.22 U _{oper} -1.27	SHGC _{all} - NR SHGC _{north} - NR
30.1-40.0%	U _{fixed} -0.57 U _{oper} -0.67	SHGC _{all} - 0.39 SHGC _{north} - 0.49	U _{fixed} -0.57 U _{oper} -0.67	SHGC _{all} - 0.39 SHGC _{north} - 0.49	U _{fixed} -1.22 U _{oper} -1.27	SHGC _{all} - NR SHGC _{north} - NR
40.1-50.0%	U _{fixed} -0.46 U _{oper} -0.47	SHGC _{all} - 0.25 SHGC _{north} - 0.36	U _{fixed} -0.46 U _{oper} -0.47	SHGC _{all} - 0.25 SHGC _{north} - 0.36	U _{fixed} -0.98 U _{oper} -1.02	SHGC _{all} - NR SHGC _{north} - NR
Skylight with Curb, Glass, % of Roof						
0-2.0%	U _{all} -1.17	SHGC _{all} - 0.49	U _{all} -0.98	SHGC _{all} - 0.36	U _{all} -1.98	SHGC _{all} - NR
2.1-5.0%	U _{all} -1.17	SHGC _{all} - 0.39	U _{all} -0.98	SHGC _{all} - 0.19	U _{all} -1.98	SHGC _{all} - NR
Skylight with Curb, Plastic, % of Roof						
0-2.0%	U _{all} -1.30	SHGC _{all} - 0.65	U _{all} -1.30	SHGC _{all} - 0.62	U _{all} -1.90	SHGC _{all} - NR
2.1-5.0%	U _{all} -1.30	SHGC _{all} - 0.34	U _{all} -1.30	SHGC _{all} - 0.27	U _{all} -1.90	SHGC _{all} - NR
Skylight without Curb, All, % of Roof						
0-2.0%	U _{all} -0.69	SHGC _{all} - 0.49	U _{all} -0.58	SHGC _{all} - 0.36	U _{all} -1.36	SHGC _{all} - NR
2.1-5.0%	U _{all} -0.69	SHGC _{all} - 0.39	U _{all} -0.58	SHGC _{all} - 0.19	U _{all} -1.36	SHGC _{all} - NR

* Exception to 5.3.1.2a applies

Note that all fenestration criteria are expressed in terms of a maximum U-factor and a maximum solar heat gain coefficient. There are two classes of vertical fenestration: fixed windows and operable windows. There are three classes of skylights: glass skylights on a curb, plastic skylights on a curb and skylights (either glass or plastic) without a curb. Note also that the criteria are related to the area of vertical fenestration or skylights. Area is expressed as the window-wall ratio for windows and as a percent of the roof area for skylights. Both fenestration U-factor and SHGC must be calculated using the procedures of the National Fenestration Rating Council (NFRC).

Appendix B – Glazing Constructions

ID	ID Number	Class	Name	U Factor Set	U Vert W41	U Sky Curb W41	U Sky No Curb W41	SC	SHGC	VLT	VLT/SHGC	Initial Cost	U Vert Oper Map	U Vert Fixed Map	U Sky Curb Map	U Sky No Curb Map	Include Vert Oper	Include Vert Fixed	Include Sky Curb	Include Sky No Curb	LCC
1	1101	Glass	Mtl/Clr	Yes	1.26	1.58	1.37	0.95	0.82	0.8	0.98	0.00	1.27	1.22	1.98	1.36	Yes	Yes	Yes	Yes	0
2	1102	Glass	Mtl/Grn	Yes	1.26	1.58	1.36	0.71	0.61	0.67	1.10	0.51	1.27	1.22	1.98	1.36	Yes	Yes	Yes	Yes	0
3	1103	Glass	Mtl/Hpt	Yes	1.27	1.58	1.37	0.64	0.55	0.6	1.09	1.43	1.27	1.22	1.98	1.36	Yes	Yes	Yes	Yes	0
4	1104	Glass	Mtl/ClrMpr	Yes	1.26	1.58	1.36	0.67	0.58	0.47	0.81	2.18	1.27	1.22	1.98	1.36	Yes	Yes	Yes	Yes	0
5	1105	Glass	Mtl/GrnMpr	Yes	1.26	1.58	1.36	0.51	0.44	0.39	0.89	2.69	1.27	1.22	1.98	1.36	Yes	Yes	Yes	Yes	0
6	1106	Glass	Mtl/HptMpr	Yes	1.26	1.58	1.36	0.47	0.4	0.38	0.95	3.61	1.27	1.22	1.98	1.36	Yes	Yes	Yes	Yes	0
7	1301	Glass	Brk/Clr	Yes	1.15	1.53	1.26	0.92	0.79	0.8	1.01	1.95	1.08	1.11	1.89	1.25	Yes	Yes	Yes	Yes	0
8	1302	Glass	Brk/Grn	No	1.15	1.53	1.25	0.67	0.58	0.67	1.16	2.46	1.08	1.11	1.89	1.25	Yes	Yes	Yes	Yes	0
9	1303	Glass	Brk/Hpt	No	1.15	1.53	1.26	0.59	0.51	0.6	1.18	3.38	1.08	1.11	1.89	1.25	Yes	Yes	Yes	Yes	0
10	1304	Glass	Brk/ClrMpr	No	1.15	1.53	1.25	0.64	0.55	0.47	0.85	4.13	1.08	1.11	1.89	1.25	Yes	Yes	Yes	Yes	0
11	1305	Glass	Brk/GrnMpr	No	1.15	1.53	1.25	0.48	0.41	0.39	0.95	4.64	1.08	1.11	1.89	1.25	Yes	Yes	Yes	Yes	0
12	1306	Glass	Brk/HptMpr	No	1.15	1.53	1.25	0.43	0.37	0.38	1.03	5.56	1.08	1.11	1.89	1.25	Yes	Yes	Yes	Yes	0
13	1501	Glass	Vnl/Clr	Yes	1.02	1.47	1.12	0.85	0.73	0.77	1.05	5.20	0.89	0.98	1.75	0	Yes	Yes	Yes	No	0
14	1502	Glass	Vnl/Grn	No	1.02	1.47	1.12	0.62	0.53	0.64	1.21	5.71	0.89	0.98	1.75	0	Yes	Yes	Yes	No	0
15	1503	Glass	Vnl/Hpt	No	1.02	1.47	1.12	0.55	0.47	0.58	1.23	6.63	0.89	0.98	1.75	0	Yes	Yes	Yes	No	0
16	1504	Glass	Vnl/ClrMpr	No	1.02	1.47	1.12	0.58	0.5	0.45	0.90	7.38	0.89	0.98	1.75	0	Yes	Yes	Yes	No	0
17	1505	Glass	Vnl/GrnMpr	No	1.02	1.47	1.12	0.43	0.37	0.37	1.00	7.89	0.89	0.98	1.75	0	Yes	Yes	Yes	No	0
18	1506	Glass	Vnl/HptMpr	No	1.02	1.47	1.12	0.38	0.33	0.37	1.12	8.81	0.89	0.98	1.75	0	Yes	Yes	Yes	No	0
19	2111	Glass	Mtl/Clr-Std-Clr	Yes	0.73	0.96	0.81	0.84	0.72	0.71	0.99	3.93	0.81	0.73	1.3	0.81	Yes	Yes	Yes	Yes	0

ID	IDNumber	Class	Name	UfactorSet	UVertW41	USkyCurbW41	USkyNoCurbW41	SC	SHGC	VLT	VLT/SHGC	InitialCost	UVertOperMap	UVertFixedMap	USkyCurbMap	USkyNoCurbMap	IncludeVertOper	IncludeVertFixed	IncludeSkyCurb	IncludeSkyNoCurb	LCC
20	2112	Glass	Mtl/Grn-Std-Clr	No	0.73	0.96	0.81	0.59	0.51	0.6	1.18	4.43	0.81	0.73	1.3	0.81	Yes	Yes	Yes	Yes	0
21	2113	Glass	Mtl/Hpt-Std-Clr	No	0.73	0.96	0.81	0.51	0.44	0.54	1.23	5.36	0.81	0.73	1.3	0.81	Yes	Yes	Yes	Yes	0
22	2114	Glass	Mtl/ClrMpr-Std-Clr	No	0.73	0.96	0.81	0.58	0.5	0.43	0.86	6.11	0.81	0.73	1.3	0.81	Yes	Yes	Yes	Yes	0
23	2115	Glass	Mtl/GrnMpr-Std-Clr	No	0.73	0.96	0.81	0.42	0.36	0.35	0.97	6.62	0.81	0.73	1.3	0.81	Yes	Yes	Yes	Yes	0
24	2116	Glass	Mtl/HptMpr-Std-Clr	No	0.73	0.96	0.81	0.37	0.32	0.34	1.06	7.54	0.81	0.73	1.3	0.81	Yes	Yes	Yes	Yes	0
25	2117	Glass	Mtl/ClrSbe-Std-Clr	No	0.59	0.84	0.69	0.51	0.44	0.45	1.02	6.37	0.69	0.59	1.18	0.7	Yes	Yes	Yes	Yes	0
26	2118	Glass	Mtl/GrnSbe-Std-Clr	No	0.59	0.84	0.69	0.4	0.34	0.39	1.15	6.88	0.69	0.59	1.18	0.7	Yes	Yes	Yes	Yes	0
27	2119	Glass	Mtl/HptSbe-Std-Clr	No	0.59	0.84	0.69	0.35	0.3	0.34	1.13	7.80	0.69	0.59	1.18	0.7	Yes	Yes	Yes	Yes	0
28	2121	Glass	Mtl/Clr-Std-ClrPye	Yes	0.6	0.85	0.7	0.79	0.68	0.66	0.97	5.23	0.71	0.62	1.2	0.71	Yes	Yes	Yes	Yes	0
29	2122	Glass	Mtl/Grn-Std-ClrPye	No	0.6	0.85	0.7	0.53	0.46	0.55	1.20	5.73	0.71	0.62	1.2	0.71	Yes	Yes	Yes	Yes	0
30	2123	Glass	Mtl/Hpt-Std-ClrPye	No	0.6	0.85	0.7	0.45	0.39	0.5	1.28	6.66	0.71	0.62	1.2	0.71	Yes	Yes	Yes	Yes	0
31	2124	Glass	Mtl/ClrMpr-Std-ClrPye	No	0.6	0.85	0.7	0.56	0.48	0.4	0.83	7.41	0.71	0.62	1.2	0.71	Yes	Yes	Yes	Yes	0
32	2125	Glass	Mtl/GrnMpr-Std-ClrPye	No	0.6	0.85	0.7	0.38	0.33	0.33	1.00	7.92	0.71	0.62	1.2	0.71	Yes	Yes	Yes	Yes	0
33	2126	Glass	Mtl/HptMpr-Std-ClrPye	No	0.6	0.85	0.7	0.34	0.29	0.32	1.10	8.84	0.71	0.62	1.2	0.71	Yes	Yes	Yes	Yes	0
34	2131	Glass	Mtl/Clr-Std-ClrSpe	Yes	0.59	0.84	0.69	0.7	0.6	0.66	1.10	6.37	0.69	0.59	1.18	0.7	Yes	Yes	Yes	Yes	0
35	2132	Glass	Mtl/Grn-Std-ClrSpe	No	0.59	0.84	0.69	0.5	0.43	0.55	1.28	6.88	0.69	0.59	1.18	0.7	Yes	Yes	Yes	Yes	0
36	2133	Glass	Mtl/Hpt-Std-ClrSpe	No	0.59	0.84	0.69	0.44	0.38	0.49	1.29	7.80	0.69	0.59	1.18	0.7	Yes	Yes	Yes	Yes	0
37	2134	Glass	Mtl/ClrMpr-Std-ClrSpe	No	0.59	0.84	0.69	0.49	0.42	0.39	0.93	8.55	0.69	0.59	1.18	0.7	Yes	Yes	Yes	Yes	0
38	2135	Glass	Mtl/GrnMpr-Std-ClrSpe	No	0.59	0.84	0.69	0.35	0.3	0.32	1.07	9.06	0.69	0.59	1.18	0.7	Yes	Yes	Yes	Yes	0
39	2136	Glass	Mtl/HptMpr-Std-ClrSpe	No	0.59	0.84	0.69	0.3	0.26	0.32	1.23	9.98	0.69	0.59	1.18	0.7	Yes	Yes	Yes	Yes	0
40	2141	Glass	Mtl/Clr-Std-ClrSue	Yes	0.57	0.83	0.68	0.57	0.49	0.62	1.27	5.88	0.67	0.57	1.17	0.69	Yes	Yes	Yes	Yes	0

ID	IDNumber	Class	Name	UfactorSet	UVertW41	USkyCurbW41	USkyNoCurbW41	SC	SHGC	VLT	VLT/SHGC	InitialCost	UVertOperMap	UVertFixedMap	USkyCurbMap	USkyNoCurbMap	IncludeVertOper	IncludeVertFixed	IncludeSkyCurb	IncludeSkyNoCurb	LCC
41	2142	Glass	Mtl/Grn-Std-ClrSue	No	0.57	0.83	0.68	0.45	0.39	0.52	1.33	6.38	0.67	0.57	1.17	0.69	Yes	Yes	Yes	Yes	0
42	2143	Glass	Mtl/Hpt-Std-ClrSue	No	0.57	0.83	0.68	0.41	0.35	0.47	1.34	7.31	0.67	0.57	1.17	0.69	Yes	Yes	Yes	Yes	0
43	2144	Glass	Mtl/ClrMpr-Std-ClrSue	No	0.57	0.83	0.68	0.41	0.35	0.37	1.06	8.06	0.67	0.57	1.17	0.69	Yes	Yes	Yes	Yes	0
44	2145	Glass	Mtl/GrnMpr-Std-ClrSue	No	0.57	0.83	0.68	0.29	0.25	0.31	1.24	8.57	0.67	0.57	1.17	0.69	Yes	Yes	Yes	Yes	0
45	2146	Glass	Mtl/HptMpr-Std-ClrSue	No	0.57	0.83	0.68	0.27	0.23	0.3	1.30	9.49	0.67	0.57	1.17	0.69	Yes	Yes	Yes	Yes	0
46	2150	Glass	Mtl/ClrPye-Std-ClrPye	No	0.58	0.84	0.69	0.71	0.61	0.62	1.02	6.53	0	0	0	0	No	No	No	No	0
47	2160	Glass	Mtl/ClrSpe-Std-ClrSpe	No	0.57	0.83	0.68	0.59	0.51	0.61	1.20	8.81	0	0	0	0	No	No	No	No	0
48	2170	Glass	Mtl/ClrSue-Std-ClrSue	No	0.57	0.82	0.68	0.47	0.4	0.55	1.38	7.83	0	0	0	0	No	No	No	No	0
49	2311	Glass	Brk/Clr-Std-Clr	Yes	0.62	0.85	0.7	0.79	0.68	0.71	1.04	5.88	0.6	0.62	1.1	0.69	Yes	Yes	Yes	Yes	0
50	2312	Glass	Brk/Grn-Std-Clr	No	0.62	0.84	0.69	0.55	0.47	0.6	1.28	6.38	0.6	0.62	1.1	0.69	Yes	Yes	Yes	Yes	0
51	2313	Glass	Brk/Hpt-Std-Clr	No	0.62	0.85	0.7	0.47	0.4	0.54	1.35	7.31	0.6	0.62	1.1	0.69	Yes	Yes	Yes	Yes	0
52	2314	Glass	Brk/ClrMpr-Std-Clr	No	0.62	0.84	0.7	0.55	0.47	0.43	0.91	8.06	0.6	0.62	1.1	0.69	Yes	Yes	Yes	Yes	0
53	2315	Glass	Brk/GrnMpr-Std-Clr	No	0.62	0.84	0.7	0.38	0.33	0.35	1.06	8.57	0.6	0.62	1.1	0.69	Yes	Yes	Yes	Yes	0
54	2316	Glass	Brk/HptMpr-Std-Clr	No	0.62	0.84	0.7	0.33	0.28	0.34	1.21	9.49	0.6	0.62	1.1	0.69	Yes	Yes	Yes	Yes	0
55	2317	Glass	Brk/ClrSbe-Std-Clr	No	0.48	0.73	0.58	0.47	0.4	0.45	1.13	8.32	0.49	0.48	0.99	0.58	Yes	Yes	Yes	Yes	0
56	2318	Glass	Brk/GrnSbe-Std-Clr	No	0.48	0.73	0.58	0.36	0.31	0.39	1.26	8.83	0.49	0.48	0.99	0.58	Yes	Yes	Yes	Yes	0
57	2319	Glass	Brk/HptSbe-Std-Clr	No	0.48	0.73	0.58	0.3	0.26	0.34	1.31	9.75	0.49	0.48	0.99	0.58	Yes	Yes	Yes	Yes	0
58	2321	Glass	Brk/Clr-Std-ClrPye	Yes	0.49	0.74	0.59	0.74	0.64	0.66	1.03	7.18	0.51	0.51	1	0.6	Yes	Yes	Yes	Yes	0
59	2322	Glass	Brk/Grn-Std-ClrPye	No	0.49	0.74	0.59	0.5	0.43	0.55	1.28	7.68	0.51	0.51	1	0.6	Yes	Yes	Yes	Yes	0
60	2323	Glass	Brk/Hpt-Std-ClrPye	No	0.49	0.74	0.59	0.42	0.36	0.5	1.39	8.61	0.51	0.51	1	0.6	Yes	Yes	Yes	Yes	0
61	2324	Glass	Brk/ClrMpr-Std-ClrPye	No	0.49	0.74	0.59	0.51	0.44	0.4	0.91	9.36	0.51	0.51	1	0.6	Yes	Yes	Yes	Yes	0

ID	IDNumber	Class	Name	UfactorSet	UVertW41	USkyCurbW41	USkyNoCurbW41	SC	SHGC	VLT	VLT/SHGC	InitialCost	UVertOperMap	UVertFixedMap	USkyCurbMap	USkyNoCurbMap	IncludeVertOper	IncludeVertFixed	IncludeSkyCurb	IncludeSkyNoCurb	LCC
62	2325	Glass	Brk/GrnMpr-Std-ClrPye	No	0.49	0.74	0.59	0.35	0.3	0.33	1.10	9.87	0.51	0.51	1	0.6	Yes	Yes	Yes	Yes	0
63	2326	Glass	Brk/HptMpr-Std-ClrPye	No	0.49	0.74	0.59	0.29	0.25	0.32	1.28	10.79	0.51	0.51	1	0.6	Yes	Yes	Yes	Yes	0
64	2331	Glass	Brk/Clr-Std-ClrSpe	Yes	0.48	0.73	0.58	0.65	0.56	0.66	1.18	8.32	0.49	0.48	0.99	0.58	Yes	Yes	Yes	Yes	0
65	2332	Glass	Brk/Grn-Std-ClrSpe	No	0.48	0.73	0.58	0.47	0.4	0.55	1.38	8.83	0.49	0.48	0.99	0.58	Yes	Yes	Yes	Yes	0
66	2333	Glass	Brk/Hpt-Std-ClrSpe	No	0.48	0.73	0.58	0.4	0.34	0.49	1.44	9.75	0.49	0.48	0.99	0.58	Yes	Yes	Yes	Yes	0
67	2334	Glass	Brk/ClrMpr-Std-ClrSpe	No	0.48	0.73	0.58	0.45	0.39	0.39	1.00	10.50	0.49	0.48	0.99	0.58	Yes	Yes	Yes	Yes	0
68	2335	Glass	Brk/GrnMpr-Std-ClrSpe	No	0.48	0.73	0.58	0.3	0.26	0.32	1.23	11.01	0.49	0.48	0.99	0.58	Yes	Yes	Yes	Yes	0
69	2336	Glass	Brk/HptMpr-Std-ClrSpe	No	0.48	0.73	0.58	0.27	0.23	0.32	1.39	11.93	0.49	0.48	0.99	0.58	Yes	Yes	Yes	Yes	0
70	2341	Glass	Brk/Clr-Std-ClrSue	Yes	0.46	0.71	0.57	0.53	0.46	0.62	1.35	7.83	0.47	0.46	0.98	0.58	Yes	Yes	Yes	Yes	0
71	2342	Glass	Brk/Grn-Std-ClrSue	No	0.46	0.71	0.57	0.42	0.36	0.52	1.44	8.33	0.47	0.46	0.98	0.58	Yes	Yes	Yes	Yes	0
72	2343	Glass	Brk/Hpt-Std-ClrSue	No	0.46	0.71	0.57	0.37	0.32	0.47	1.47	9.26	0.47	0.46	0.98	0.58	Yes	Yes	Yes	Yes	0
73	2344	Glass	Brk/ClrMpr-Std-ClrSue	No	0.46	0.71	0.57	0.36	0.31	0.37	1.19	10.01	0.47	0.46	0.98	0.58	Yes	Yes	Yes	Yes	0
74	2345	Glass	Brk/GrnMpr-Std-ClrSue	No	0.46	0.71	0.57	0.26	0.22	0.31	1.41	10.52	0.47	0.46	0.98	0.58	Yes	Yes	Yes	Yes	0
75	2346	Glass	Brk/HptMpr-Std-ClrSue	No	0.46	0.71	0.57	0.22	0.19	0.3	1.58	11.44	0.47	0.46	0.98	0.58	Yes	Yes	Yes	Yes	0
76	2350	Glass	Brk/ClrPye-Std-ClrPye	No	0.47	0.72	0.58	0.67	0.58	0.62	1.07	8.48	0	0	0	0	No	No	No	No	0
77	2360	Glass	Brk/ClrSpe-Std-ClrSpe	No	0.46	0.72	0.57	0.56	0.48	0.61	1.27	10.76	0	0	0	0	No	No	No	No	0
78	2370	Glass	Brk/ClrSue-Std-ClrSue	No	0.46	0.71	0.56	0.43	0.37	0.55	1.49	9.78	0	0	0	0	No	No	No	No	0
79	2411	Glass	Brk/Clr-Ins-Clr	Yes	0.59	0.81	0.67	0.79	0.68	0.71	1.04	6.92	0.57	0.59	1.07	0.66	Yes	Yes	Yes	Yes	0
80	2412	Glass	Brk/Grn-Ins-Clr	No	0.59	0.81	0.67	0.55	0.47	0.6	1.28	7.42	0.57	0.59	1.07	0.66	Yes	Yes	Yes	Yes	0
81	2413	Glass	Brk/Hpt-Ins-Clr	No	0.59	0.81	0.67	0.47	0.4	0.54	1.35	8.35	0.57	0.59	1.07	0.66	Yes	Yes	Yes	Yes	0
82	2414	Glass	Brk/ClrMpr-Ins-Clr	No	0.59	0.81	0.67	0.55	0.47	0.43	0.91	9.10	0.57	0.59	1.07	0.66	Yes	Yes	Yes	Yes	0

ID	IDNumber	Class	Name	UfactorSet	UVertW41	USkyCurbW41	USkyNoCurbW41	SC	SHGC	VLT	VLT/SHGC	InitialCost	UVertOperMap	UVertFixedMap	USkyCurbMap	USkyNoCurbMap	IncludeVertOper	IncludeVertFixed	IncludeSkyCurb	IncludeSkyNoCurb	LCC
83	2415	Glass	Brk/GrnMpr-Ins-Clr	No	0.59	0.81	0.67	0.37	0.32	0.35	1.09	9.61	0.57	0.59	1.07	0.66	Yes	Yes	Yes	Yes	0
84	2416	Glass	Brk/HptMpr-Ins-Clr	No	0.59	0.81	0.67	0.33	0.28	0.34	1.21	10.53	0.57	0.59	1.07	0.66	Yes	Yes	Yes	Yes	0
85	2417	Glass	Brk/ClrSbe-Ins-Clr	No	0.44	0.69	0.55	0.47	0.4	0.45	1.13	9.36	0.46	0.45	0.96	0.55	Yes	Yes	Yes	Yes	0
86	2418	Glass	Brk/GrnSbe-Ins-Clr	No	0.44	0.69	0.55	0.35	0.3	0.39	1.30	9.87	0.46	0.45	0.96	0.55	Yes	Yes	Yes	Yes	0
87	2419	Glass	Brk/HptSbe-Ins-Clr	No	0.44	0.69	0.55	0.3	0.26	0.34	1.31	10.79	0.46	0.45	0.96	0.55	Yes	Yes	Yes	Yes	0
88	2421	Glass	Brk/Clr-Ins-ClrPye	Yes	0.45	0.7	0.56	0.74	0.64	0.66	1.03	8.22	0.48	0.48	0.97	0.57	Yes	Yes	Yes	Yes	0
89	2422	Glass	Brk/Grn-Ins-ClrPye	No	0.45	0.7	0.56	0.49	0.42	0.55	1.31	8.72	0.48	0.48	0.97	0.57	Yes	Yes	Yes	Yes	0
90	2423	Glass	Brk/Hpt-Ins-ClrPye	No	0.45	0.7	0.56	0.41	0.35	0.5	1.43	9.65	0.48	0.48	0.97	0.57	Yes	Yes	Yes	Yes	0
91	2424	Glass	Brk/ClrMpr-Ins-ClrPye	No	0.45	0.7	0.56	0.51	0.44	0.4	0.91	10.40	0.48	0.48	0.97	0.57	Yes	Yes	Yes	Yes	0
92	2425	Glass	Brk/GrnMpr-Ins-ClrPye	No	0.45	0.7	0.56	0.34	0.29	0.33	1.14	10.91	0.48	0.48	0.97	0.57	Yes	Yes	Yes	Yes	0
93	2426	Glass	Brk/HptMpr-Ins-ClrPye	No	0.45	0.7	0.56	0.29	0.25	0.32	1.28	11.83	0.48	0.48	0.97	0.57	Yes	Yes	Yes	Yes	0
94	2431	Glass	Brk/Clr-Ins-ClrSpe	Yes	0.44	0.69	0.55	0.65	0.56	0.66	1.18	9.36	0.46	0.45	0.96	0.55	Yes	Yes	Yes	Yes	0
95	2432	Glass	Brk/Grn-Ins-ClrSpe	No	0.44	0.69	0.55	0.47	0.4	0.55	1.38	9.87	0.46	0.45	0.96	0.55	Yes	Yes	Yes	Yes	0
96	2433	Glass	Brk/Hpt-Ins-ClrSpe	No	0.44	0.69	0.55	0.4	0.34	0.49	1.44	10.79	0.46	0.45	0.96	0.55	Yes	Yes	Yes	Yes	0
97	2434	Glass	Brk/ClrMpr-Ins-ClrSpe	No	0.44	0.69	0.55	0.44	0.38	0.39	1.03	11.54	0.46	0.45	0.96	0.55	Yes	Yes	Yes	Yes	0
98	2435	Glass	Brk/GrnMpr-Ins-ClrSpe	No	0.44	0.69	0.55	0.3	0.26	0.32	1.23	12.05	0.46	0.45	0.96	0.55	Yes	Yes	Yes	Yes	0
99	2436	Glass	Brk/HptMpr-Ins-ClrSpe	No	0.44	0.69	0.55	0.26	0.22	0.32	1.45	12.97	0.46	0.45	0.96	0.55	Yes	Yes	Yes	Yes	0
100	2441	Glass	Brk/Clr-Ins-ClrSue	Yes	0.42	0.67	0.54	0.53	0.46	0.62	1.35	8.87	0.44	0.43	0.95	0.55	Yes	Yes	Yes	Yes	0
101	2442	Glass	Brk/Grn-Ins-ClrSue	No	0.42	0.67	0.54	0.42	0.36	0.52	1.44	9.37	0.44	0.43	0.95	0.55	Yes	Yes	Yes	Yes	0
102	2443	Glass	Brk/Hpt-Ins-ClrSue	No	0.42	0.68	0.54	0.36	0.31	0.47	1.52	10.30	0.44	0.43	0.95	0.55	Yes	Yes	Yes	Yes	0
103	2444	Glass	Brk/ClrMpr-Ins-ClrSue	No	0.42	0.68	0.54	0.36	0.31	0.37	1.19	11.05	0.44	0.43	0.95	0.55	Yes	Yes	Yes	Yes	0

ID	IDNumber	Class	Name	UfactorSet	UVertW41	USkyCurbW41	USkyNoCurbW41	SC	SHGC	VLT	VLT/SHGC	InitialCost	UVertOperMap	UVertFixedMap	USkyCurbMap	USkyNoCurbMap	IncludeVertOper	IncludeVertFixed	IncludeSkyCurb	IncludeSkyNoCurb	LCC
104	2445	Glass	Brk/GrnMpr-Ins-ClrSue	No	0.42	0.68	0.54	0.26	0.22	0.31	1.41	11.56	0.44	0.43	0.95	0.55	Yes	Yes	Yes	Yes	0
105	2446	Glass	Brk/HptMpr-Ins-ClrSue	No	0.42	0.68	0.54	0.22	0.19	0.3	1.58	12.48	0.44	0.43	0.95	0.55	Yes	Yes	Yes	Yes	0
106	2450	Glass	Brk/ClrPye-Ins-ClrPye	No	0.43	0.68	0.55	0.67	0.58	0.62	1.07	9.52	0	0	0	0	No	No	No	No	0
107	2460	Glass	Brk/ClrSpe-Ins-ClrSpe	No	0.42	0.68	0.54	0.55	0.47	0.61	1.30	11.80	0	0	0	0	No	No	No	No	0
108	2470	Glass	Brk/ClrSue-Ins-ClrSue	No	0.41	0.67	0.53	0.42	0.36	0.55	1.53	10.82	0	0	0	0	No	No	No	No	0
109	2511	Glass	Vnl/Clr-Std-Clr	Yes	0.51	0.82	0.58	0.73	0.63	0.68	1.08	9.13	0.51	0.5	1.04	0	Yes	Yes	Yes	No	0
110	2512	Glass	Vnl/Grn-Std-Clr	No	0.51	0.82	0.58	0.5	0.43	0.47	1.09	9.63	0.51	0.5	1.04	0	Yes	Yes	Yes	No	0
111	2513	Glass	Vnl/Hpt-Std-Clr	No	0.51	0.82	0.58	0.42	0.36	0.51	1.42	10.56	0.51	0.5	1.04	0	Yes	Yes	Yes	No	0
112	2514	Glass	Vnl/ClrMpr-Std-Clr	No	0.51	0.82	0.58	0.49	0.42	0.41	0.98	11.31	0.51	0.5	1.04	0	Yes	Yes	Yes	No	0
113	2515	Glass	Vnl/GrnMpr-Std-Clr	No	0.51	0.82	0.58	0.34	0.29	0.34	1.17	11.82	0.51	0.5	1.04	0	Yes	Yes	Yes	No	0
114	2516	Glass	Vnl/HptMpr-Std-Clr	No	0.51	0.82	0.58	0.29	0.25	0.33	1.32	12.74	0.51	0.5	1.04	0	Yes	Yes	Yes	No	0
115	2517	Glass	Vnl/ClrSbe-Std-Clr	No	0.37	0.71	0.47	0.42	0.36	0.43	1.19	11.57	0.4	0.37	0.92	0	Yes	Yes	Yes	No	0
116	2518	Glass	Vnl/GrnSbe-Std-Clr	No	0.37	0.71	0.47	0.31	0.27	0.37	1.37	12.08	0.4	0.37	0.92	0	Yes	Yes	Yes	No	0
117	2519	Glass	Vnl/HptSbe-Std-Clr	No	0.37	0.71	0.47	0.27	0.23	0.32	1.39	13.00	0.4	0.37	0.92	0	Yes	Yes	Yes	No	0
118	2521	Glass	Vnl/Clr-Std-ClrPye	Yes	0.39	0.72	0.48	0.69	0.59	0.63	1.07	10.43	0.42	0.39	0.94	0	Yes	Yes	Yes	No	0
119	2522	Glass	Vnl/Grn-Std-ClrPye	No	0.39	0.72	0.48	0.44	0.38	0.53	1.39	10.93	0.42	0.39	0.94	0	Yes	Yes	Yes	No	0
120	2523	Glass	Vnl/Hpt-Std-ClrPye	No	0.39	0.72	0.48	0.37	0.32	0.48	1.50	11.86	0.42	0.39	0.94	0	Yes	Yes	Yes	No	0
121	2524	Glass	Vnl/ClrMpr-Std-ClrPye	No	0.39	0.72	0.48	0.47	0.4	0.39	0.98	12.61	0.42	0.39	0.94	0	Yes	Yes	Yes	No	0
122	2525	Glass	Vnl/GrnMpr-Std-ClrPye	No	0.39	0.72	0.48	0.3	0.26	0.32	1.23	13.12	0.42	0.39	0.94	0	Yes	Yes	Yes	No	0
123	2526	Glass	Vnl/HptMpr-Std-ClrPye	No	0.39	0.72	0.48	0.26	0.22	0.31	1.41	14.04	0.42	0.39	0.94	0	Yes	Yes	Yes	No	0
124	2531	Glass	Vnl/Clr-Std-ClrSpe	Yes	0.37	0.7	0.47	0.59	0.51	0.63	1.24	11.57	0.4	0.37	0.92	0	Yes	Yes	Yes	No	0

ID	IDNumber	Class	Name	UfactorSet	UVertW41	USkyCurbW41	USkyNoCurbW41	SC	SHGC	VLT	VLT/SHGC	InitialCost	UVertOperMap	UVertFixedMap	USkyCurbMap	USkyNoCurbMap	IncludeVertOper	IncludeVertFixed	IncludeSkyCurb	IncludeSkyNoCurb	LCC
125	2532	Glass	Vnl/Grn-Std-ClrSpe	No	0.37	0.7	0.47	0.42	0.36	0.53	1.47	12.08	0.4	0.37	0.92	0	Yes	Yes	Yes	No	0
126	2533	Glass	Vnl/Hpt-Std-ClrSpe	No	0.37	0.7	0.47	0.35	0.3	0.47	1.57	13.00	0.4	0.37	0.92	0	Yes	Yes	Yes	No	0
127	2534	Glass	Vnl/ClrMpr-Std-ClrSpe	No	0.37	0.7	0.47	0.41	0.35	0.38	1.09	13.75	0.4	0.37	0.92	0	Yes	Yes	Yes	No	0
128	2535	Glass	Vnl/GrnMpr-Std-ClrSpe	No	0.37	0.7	0.47	0.27	0.23	0.31	1.35	14.26	0.4	0.37	0.92	0	Yes	Yes	Yes	No	0
129	2536	Glass	Vnl/HptMpr-Std-ClrSpe	No	0.37	0.7	0.47	0.22	0.19	0.3	1.58	15.18	0.4	0.37	0.92	0	Yes	Yes	Yes	No	0
130	2541	Glass	Vnl/Clr-Std-ClrSue	Yes	0.36	0.69	0.46	0.48	0.41	0.6	1.46	11.08	0.39	0.35	0.91	0	Yes	Yes	Yes	No	0
131	2542	Glass	Vnl/Grn-Std-ClrSue	No	0.36	0.69	0.46	0.37	0.32	0.5	1.56	11.58	0.39	0.35	0.91	0	Yes	Yes	Yes	No	0
132	2543	Glass	Vnl/Hpt-Std-ClrSue	No	0.36	0.69	0.46	0.33	0.28	0.45	1.61	12.51	0.39	0.35	0.91	0	Yes	Yes	Yes	No	0
133	2544	Glass	Vnl/ClrMpr-Std-ClrSue	No	0.36	0.69	0.46	0.31	0.27	0.36	1.33	13.26	0.39	0.35	0.91	0	Yes	Yes	Yes	No	0
134	2545	Glass	Vnl/GrnMpr-Std-ClrSue	No	0.36	0.69	0.46	0.22	0.19	0.3	1.58	13.77	0.39	0.35	0.91	0	Yes	Yes	Yes	No	0
135	2546	Glass	Vnl/HptMpr-Std-ClrSue	No	0.36	0.69	0.46	0.19	0.16	0.29	1.81	14.69	0.39	0.35	0.91	0	Yes	Yes	Yes	No	0
136	2550	Glass	Vnl/ClrPye-Std-ClrPye	No	0.37	0.7	0.47	0.62	0.53	0.59	1.11	11.73	0	0	0	0	No	No	No	No	0
137	2560	Glass	Vnl/ClrSpe-Std-ClrSpe	No	0.36	0.69	0.46	0.5	0.43	0.58	1.35	14.01	0	0	0	0	No	No	No	No	0
138	2570	Glass	Vnl/ClrSue-Std-ClrSue	No	0.35	0.69	0.46	0.38	0.33	0.52	1.58	13.03	0	0	0	0	No	No	No	No	0
139	2611	Glass	Vnl/Clr-Ins-Clr	Yes	0.48	0.82	0.56	0.73	0.63	0.68	1.08	10.17	0.48	0.47	1.01	0	Yes	Yes	Yes	No	0
140	2612	Glass	Vnl/Grn-Ins-Clr	No	0.48	0.82	0.56	0.5	0.43	0.47	1.09	10.67	0.48	0.47	1.01	0	Yes	Yes	Yes	No	0
141	2613	Glass	Vnl/Hpt-Ins-Clr	No	0.48	0.82	0.56	0.42	0.36	0.51	1.42	11.60	0.48	0.47	1.01	0	Yes	Yes	Yes	No	0
142	2614	Glass	Vnl/ClrMpr-Ins-Clr	No	0.48	0.82	0.56	0.49	0.42	0.41	0.98	12.35	0.48	0.47	1.01	0	Yes	Yes	Yes	No	0
143	2615	Glass	Vnl/GrnMpr-Ins-Clr	No	0.48	0.82	0.56	0.34	0.29	0.34	1.17	12.86	0.48	0.47	1.01	0	Yes	Yes	Yes	No	0
144	2616	Glass	Vnl/HptMpr-Ins-Clr	No	0.48	0.82	0.56	0.28	0.24	0.33	1.38	13.78	0.48	0.47	1.01	0	Yes	Yes	Yes	No	0
145	2617	Glass	Vnl/ClrSbe-Ins-Clr	No	0.34	0.7	0.44	0.42	0.36	0.43	1.19	12.61	0.37	0.34	0.89	0	Yes	Yes	Yes	No	0

ID	IDNumber	Class	Name	UfactorSet	UVertW41	USkyCurbW41	USkyNoCurbW41	SC	SHGC	VLT	VLT/SHGC	InitialCost	UVertOperMap	UVertFixedMap	USkyCurbMap	USkyNoCurbMap	IncludeVertOper	IncludeVertFixed	IncludeSkyCurb	IncludeSkyNoCurb	LCC
146	2618	Glass	Vnl/GrnSbe-Ins-Clr	No	0.34	0.7	0.44	0.31	0.27	0.37	1.37	13.12	0.37	0.34	0.89	0	Yes	Yes	Yes	No	0
147	2619	Glass	Vnl/HptSbe-Ins-Clr	No	0.34	0.7	0.44	0.26	0.22	0.32	1.45	14.04	0.37	0.34	0.89	0	Yes	Yes	Yes	No	0
148	2621	Glass	Vnl/Clr-Ins-ClrPye	Yes	0.35	0.71	0.45	0.69	0.59	0.63	1.07	11.47	0.39	0.34	0.91	0	Yes	Yes	Yes	No	0
149	2622	Glass	Vnl/Grn-Ins-ClrPye	No	0.35	0.71	0.45	0.44	0.38	0.53	1.39	11.97	0.39	0.34	0.91	0	Yes	Yes	Yes	No	0
150	2623	Glass	Vnl/Hpt-Ins-ClrPye	No	0.35	0.71	0.45	0.36	0.31	0.48	1.55	12.90	0.39	0.34	0.91	0	Yes	Yes	Yes	No	0
151	2624	Glass	Vnl/ClrMpr-Ins-ClrPye	No	0.35	0.71	0.45	0.47	0.4	0.39	0.98	13.65	0.39	0.34	0.91	0	Yes	Yes	Yes	No	0
152	2625	Glass	Vnl/GrnMpr-Ins-ClrPye	No	0.35	0.71	0.45	0.3	0.26	0.32	1.23	14.16	0.39	0.34	0.91	0	Yes	Yes	Yes	No	0
153	2626	Glass	Vnl/HptMpr-Ins-ClrPye	No	0.35	0.71	0.45	0.24	0.21	0.31	1.48	15.08	0.39	0.34	0.91	0	Yes	Yes	Yes	No	0
154	2631	Glass	Vnl/Clr-Ins-ClrSpe	Yes	0.33	0.7	0.44	0.59	0.51	0.63	1.24	12.61	0.37	0.34	0.89	0	Yes	Yes	Yes	No	0
155	2632	Glass	Vnl/Grn-Ins-ClrSpe	No	0.33	0.7	0.44	0.41	0.35	0.53	1.51	13.12	0.37	0.34	0.89	0	Yes	Yes	Yes	No	0
156	2633	Glass	Vnl/Hpt-Ins-ClrSpe	No	0.34	0.7	0.44	0.35	0.3	0.47	1.57	14.04	0.37	0.34	0.89	0	Yes	Yes	Yes	No	0
157	2634	Glass	Vnl/ClrMpr-Ins-ClrSpe	No	0.34	0.7	0.44	0.4	0.34	0.38	1.12	14.79	0.37	0.34	0.89	0	Yes	Yes	Yes	No	0
158	2635	Glass	Vnl/GrnMpr-Ins-ClrSpe	No	0.34	0.7	0.44	0.26	0.22	0.31	1.41	15.30	0.37	0.34	0.89	0	Yes	Yes	Yes	No	0
159	2636	Glass	Vnl/HptMpr-Ins-ClrSpe	No	0.34	0.7	0.44	0.22	0.19	0.3	1.58	16.22	0.37	0.34	0.89	0	Yes	Yes	Yes	No	0
160	2641	Glass	Vnl/Clr-Ins-ClrSue	Yes	0.32	0.68	0.43	0.48	0.41	0.6	1.46	12.12	0.36	0.32	0.88	0	Yes	Yes	Yes	No	0
161	2642	Glass	Vnl/Grn-Ins-ClrSue	No	0.32	0.68	0.43	0.37	0.32	0.5	1.56	12.62	0.36	0.32	0.88	0	Yes	Yes	Yes	No	0
162	2643	Glass	Vnl/Hpt-Ins-ClrSue	No	0.32	0.68	0.43	0.31	0.27	0.45	1.67	13.55	0.36	0.32	0.88	0	Yes	Yes	Yes	No	0
163	2644	Glass	Vnl/ClrMpr-Ins-ClrSue	No	0.32	0.68	0.43	0.31	0.27	0.36	1.33	14.30	0.36	0.32	0.88	0	Yes	Yes	Yes	No	0
164	2645	Glass	Vnl/GrnMpr-Ins-ClrSue	No	0.32	0.68	0.43	0.21	0.18	0.3	1.67	14.81	0.36	0.32	0.88	0	Yes	Yes	Yes	No	0
165	2646	Glass	Vnl/HptMpr-Ins-ClrSue	No	0.32	0.68	0.43	0.19	0.16	0.29	1.81	15.73	0.36	0.32	0.88	0	Yes	Yes	Yes	No	0
166	2650	Glass	Vnl/ClrPye-Ins-ClrPye	No	0.33	0.69	0.44	0.62	0.53	0.59	1.11	12.77	0	0	0	0	No	No	No	No	0

ID	IDNumber	Class	Name	UfactorSet	UVertW41	USkyCurbW41	USkyNoCurbW41	SC	SHGC	VLT	VLT/SHGC	InitialCost	UVertOperMap	UVertFixedMap	USkyCurbMap	USkyNoCurbMap	IncludeVertOper	IncludeVertFixed	IncludeSkyCurb	IncludeSkyNoCurb	LCC
167	2660	Glass	Vnl/ClrSpe-Ins-ClrSpe	No	0.32	0.69	0.43	0.5	0.43	0.58	1.35	15.05	0	0	0	0	No	No	No	No	0
168	2670	Glass	Vnl/ClrSue-Ins-ClrSue	No	0.31	0.68	0.43	0.37	0.32	0.52	1.63	14.07	0	0	0	0	No	No	No	No	0
169	3411	Glass	Brk/Clr-Ins-Clr-Ins-Clr	Yes	0.42	0.58	0.47	0.69	0.59	0.64	1.08	10.84	0.43	0.43	0.84	0.48	Yes	Yes	Yes	Yes	0
170	3421	Glass	Brk/Clr-Ins-V22-Ins-Clr	No	0.33	0.51	0.4	0.19	0.16	0.17	1.06	15.17	0.33	0.32	0.73	0.38	Yes	Yes	Yes	Yes	0
171	3431	Glass	Brk/Clr-Ins-V32-Ins-Clr	No	0.33	0.51	0.4	0.24	0.21	0.25	1.19	15.17	0.33	0.32	0.73	0.38	Yes	Yes	Yes	Yes	0
172	3441	Glass	Brk/Clr-Ins-V44-Ins-Clr	No	0.34	0.51	0.4	0.3	0.26	0.34	1.31	15.17	0.33	0.32	0.73	0.38	Yes	Yes	Yes	Yes	0
173	3451	Glass	Brk/Clr-Ins-V54-Ins-Clr	No	0.34	0.51	0.4	0.35	0.3	0.41	1.37	15.17	0.33	0.32	0.73	0.38	Yes	Yes	Yes	Yes	0
174	3461	Glass	Brk/Clr-Ins-V65-Ins-Clr	No	0.34	0.51	0.4	0.41	0.35	0.48	1.37	15.17	0.33	0.32	0.73	0.38	Yes	Yes	Yes	Yes	0
175	3471	Glass	Brk/Clr-Ins-V79-Ins-Clr	No	0.35	0.52	0.41	0.5	0.43	0.57	1.33	15.17	0.33	0.32	0.73	0.38	Yes	Yes	Yes	Yes	0
176	3481	Glass	Brk/Clr-Ins-V88-Ins-Clr	Yes	0.35	0.52	0.41	0.62	0.53	0.63	1.19	15.17	0.33	0.32	0.73	0.38	Yes	Yes	Yes	Yes	0
177	3611	Glass	Vnl/Clr-Ins-Clr-Ins-Clr	Yes	0.33	0.61	0.37	0.64	0.55	0.61	1.11	14.09	0.36	0.33	0.78	0	Yes	Yes	Yes	No	0
178	3621	Glass	Vnl/Clr-Ins-V22-Ins-Clr	No	0.24	0.54	0.3	0.15	0.13	0.17	1.31	18.42	0.27	0.22	0.68	0	Yes	Yes	Yes	No	0
179	3631	Glass	Vnl/Clr-Ins-V32-Ins-Clr	No	0.24	0.54	0.3	0.21	0.18	0.24	1.33	18.42	0.27	0.22	0.68	0	Yes	Yes	Yes	No	0
180	3641	Glass	Vnl/Clr-Ins-V44-Ins-Clr	No	0.24	0.54	0.31	0.26	0.22	0.32	1.45	18.42	0.27	0.22	0.68	0	Yes	Yes	Yes	No	0
181	3651	Glass	Vnl/Clr-Ins-V54-Ins-Clr	No	0.24	0.54	0.31	0.31	0.27	0.39	1.44	18.42	0.27	0.22	0.68	0	Yes	Yes	Yes	No	0
182	3661	Glass	Vnl/Clr-Ins-V65-Ins-Clr	No	0.24	0.54	0.31	0.36	0.31	0.46	1.48	18.42	0.27	0.22	0.68	0	Yes	Yes	Yes	No	0
183	3671	Glass	Vnl/Clr-Ins-V79-Ins-Clr	No	0.25	0.55	0.31	0.45	0.39	0.55	1.41	18.42	0.27	0.22	0.68	0	Yes	Yes	Yes	No	0
184	3681	Glass	Vnl/Clr-Ins-V88-Ins-Clr	Yes	0.26	0.55	0.32	0.56	0.48	0.61	1.27	18.42	0.27	0.22	0.68	0	Yes	Yes	Yes	No	0
185	4890	Glass	Vis/ClrSue-Ins-Clr-Ins-Clr-Ins-ClrSue	Yes	0.16	0	0.19	0.3	0.26	0.42	1.62	19.53	0.21	0.18	0	0	Yes	Yes	No	No	0
186	0	Plastic	AcrSglClrMtl	Yes	0	1.92	0	0.97	0.83	0.92	1.10	0.00	0	0	1.9	0	No	No	Yes	No	0
187	0	Plastic	AcrSglHWMtl	Yes	0	1.92	0	0.76	0.65	0.82	1.25	0.65	0	0	1.9	0	No	No	Yes	No	0

ID	IDNumber	Class	Name	UfactorSet	UVertW41	USkyCurbW41	USkyNoCurbW41	SC	SHGC	VLT	VLT/SHGC	InitialCost	UVertOperMap	UVertFixedMap	USkyCurbMap	USkyNoCurbMap	IncludeVertOper	IncludeVertFixed	IncludeSkyCurb	IncludeSkyNoCurb	LCC
188	0	Plastic	AcrSglMWMtl	Yes	0	1.92	0	0.68	0.58	0.53	0.91	0.65	0	0	1.9	0	No	No	Yes	No	0
189	0	Plastic	AcrSglLWMtl	Yes	0	1.92	0	0.45	0.38	0.32	0.83	0.65	0	0	1.9	0	No	No	Yes	No	0
190	0	Plastic	AcrSglBrzMtl	Yes	0	1.92	0	0.53	0.45	0.27	0.59	0.65	0	0	1.9	0	No	No	Yes	No	0
191	0	Plastic	AcrSglClrBrk	Yes	0	1.93	0	0.97	0.83	0.92	1.10	0.91	0	0	1.81	0	No	No	Yes	No	0
192	0	Plastic	AcrSglHWBrk	No	0	1.93	0	0.76	0.65	0.82	1.25	1.56	0	0	1.81	0	No	No	Yes	No	0
193	0	Plastic	AcrSglMWBrk	No	0	1.93	0	0.68	0.58	0.53	0.91	1.56	0	0	1.81	0	No	No	Yes	No	0
194	0	Plastic	AcrSglLWBrk	No	0	1.93	0	0.45	0.38	0.32	0.83	1.56	0	0	1.81	0	No	No	Yes	No	0
195	0	Plastic	AcrSglBrzBrk	No	0	1.93	0	0.53	0.45	0.27	0.59	1.56	0	0	1.81	0	No	No	Yes	No	0
196	0	Plastic	AcrDblClrMtl	Yes	0	1.29	0	0.89	0.76	0.89	1.16	2.60	0	0	1.3	0	No	No	Yes	No	0
197	0	Plastic	AcrDblHWMtl	No	0	1.29	0	0.72	0.61	0.75	1.21	3.25	0	0	1.3	0	No	No	Yes	No	0
198	0	Plastic	AcrDblMWMtl	No	0	1.29	0	0.63	0.54	0.49	0.90	3.25	0	0	1.3	0	No	No	Yes	No	0
199	0	Plastic	AcrDblLWMtl	No	0	1.29	0	0.4	0.34	0.29	0.84	3.25	0	0	1.3	0	No	No	Yes	No	0
200	0	Plastic	AcrDblBrzMtl	No	0	1.29	0	0.43	0.36	0.25	0.68	3.25	0	0	1.3	0	No	No	Yes	No	0
201	0	Plastic	AcrDblClrBrk	Yes	0	1.12	0	0.89	0.76	0.89	1.16	3.51	0	0	1.1	0	No	No	Yes	No	0
202	0	Plastic	AcrDblHWBrk	No	0	1.12	0	0.72	0.61	0.75	1.21	4.16	0	0	1.1	0	No	No	Yes	No	0
203	0	Plastic	AcrDblMWBrk	No	0	1.12	0	0.63	0.54	0.49	0.90	4.16	0	0	1.1	0	No	No	Yes	No	0
204	0	Plastic	AcrDblLWBrk	No	0	1.12	0	0.4	0.34	0.29	0.84	4.16	0	0	1.1	0	No	No	Yes	No	0
205	0	Plastic	AcrDblBrzBrk	No	0	1.12	0	0.43	0.36	0.25	0.68	4.16	0	0	1.1	0	No	No	Yes	No	0
206	0	Plastic	AcrTrpClrMtl	Yes	0	1.1	0	0.82	0.70	0.85	1.21	5.20	0	0	1.1	0	No	No	Yes	No	0
207	0	Plastic	AcrTrpHWMtl	No	0	1.1	0	0.68	0.58	0.69	1.18	5.85	0	0	1.1	0	No	No	Yes	No	0
208	0	Plastic	AcrTrpMWMtl	No	0	1.1	0	0.58	0.49	0.45	0.90	5.85	0	0	1.1	0	No	No	Yes	No	0

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209	0	Plastic	AcrTrpLWMtl	No	0	1.1	0	0.36	0.30	0.27	0.87	5.85	0	0	1.1	0	No	No	Yes	No	0
210	0	Plastic	AcrTrpBrzMtl	No	0	1.1	0	0.35	0.30	0.23	0.76	5.85	0	0	1.1	0	No	No	Yes	No	0
211	0	Plastic	AcrTrpClrBrk	Yes	0	0.91	0	0.82	0.70	0.85	1.21	6.11	0	0	0.87	0	No	No	Yes	No	0
212	0	Plastic	AcrTrpHWBrk	No	0	0.91	0	0.68	0.58	0.69	1.18	6.76	0	0	0.87	0	No	No	Yes	No	0
213	0	Plastic	AcrTrpMWBrk	No	0	0.91	0	0.58	0.49	0.45	0.90	6.76	0	0	0.87	0	No	No	Yes	No	0
214	0	Plastic	AcrTrpLWBrk	No	0	0.91	0	0.36	0.30	0.27	0.87	6.76	0	0	0.87	0	No	No	Yes	No	0
215	0	Plastic	AcrTrpBrzBrk	No	0	0.91	0	0.35	0.30	0.23	0.76	6.76	0	0	0.87	0	No	No	Yes	No	0
216	0	Plastic	AcrDblClrVnl	Yes	0	0.84	0	0.89	0.76	0.89	1.16	7.80	0	0	0.84	0	No	No	Yes	No	0
217	0	Plastic	AcrQudClrMtl	Yes	0	0.93	0	0.76	0.65	0.81	1.24	7.80	0	0	0.97	0	No	No	Yes	No	0
218	0	Plastic	AcrDblHVVnl	No	0	0.84	0	0.72	0.61	0.75	1.21	8.45	0	0	0.84	0	No	No	Yes	No	0
219	0	Plastic	AcrQudHWMtl	No	0	0.93	0	0.64	0.55	0.63	1.14	8.45	0	0	0.97	0	No	No	Yes	No	0
220	0	Plastic	AcrDblMWVnl	No	0	0.84	0	0.63	0.54	0.49	0.90	8.45	0	0	0.84	0	No	No	Yes	No	0
221	0	Plastic	AcrQudLWMtl	No	0	0.93	0	0.53	0.45	0.41	0.90	8.45	0	0	0.97	0	No	No	Yes	No	0
222	0	Plastic	AcrDblLWVnl	No	0	0.84	0	0.4	0.34	0.29	0.84	8.45	0	0	0.84	0	No	No	Yes	No	0
223	0	Plastic	AcrDblBrzVnl	No	0	0.84	0	0.43	0.36	0.25	0.68	8.45	0	0	0.84	0	No	No	Yes	No	0
224	0	Plastic	AcrQudBrzMtl	No	0	0.93	0	0.31	0.26	0.25	0.94	8.45	0	0	0.97	0	No	No	Yes	No	0
225	0	Plastic	AcrQudMWMtl	No	0	0.93	0	0.3	0.25	0.21	0.81	8.45	0	0	0.97	0	No	No	Yes	No	0
226	0	Plastic	AcrQudClrBrk	Yes	0	0.74	0	0.76	0.65	0.81	1.24	8.71	0	0	0.74	0	No	No	Yes	No	0
227	0	Plastic	AcrQudHWBrk	No	0	0.74	0	0.64	0.55	0.63	1.14	9.36	0	0	0.74	0	No	No	Yes	No	0
228	0	Plastic	AcrQudLWBrk	No	0	0.74	0	0.53	0.45	0.41	0.90	9.36	0	0	0.74	0	No	No	Yes	No	0
229	0	Plastic	AcrQudBrzBrk	No	0	0.74	0	0.31	0.26	0.25	0.94	9.36	0	0	0.74	0	No	No	Yes	No	0

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230	0	Plastic	AcrQudMWBrk	No	0	0.74	0	0.3	0.25	0.21	0.81	9.36	0	0	0.74	0	No	No	Yes	No	0
231	0	Plastic	AcrTrpClrVnl	Yes	0	0.65	0	0.89	0.76	0.89	1.16	10.40	0	0	0.61	0	No	No	Yes	No	0
232	0	Plastic	AcrTrpHWVnl	No	0	0.65	0	0.72	0.61	0.75	1.21	11.05	0	0	0.61	0	No	No	Yes	No	0
233	0	Plastic	AcrTrpMWVnl	No	0	0.65	0	0.63	0.54	0.49	0.90	11.05	0	0	0.61	0	No	No	Yes	No	0
234	0	Plastic	AcrTrpLWVnl	No	0	0.65	0	0.4	0.34	0.29	0.84	11.05	0	0	0.61	0	No	No	Yes	No	0
235	0	Plastic	AcrTrpBrzVnl	No	0	0.65	0	0.43	0.36	0.25	0.68	11.05	0	0	0.61	0	No	No	Yes	No	0
236	0	Plastic	AcrQudClrVnl	Yes	0	0.48	0	0.76	0.65	0.81	1.24	13.00	0	0	0.49	0	No	No	Yes	No	0
237	0	Plastic	AcrQudHWVnl	No	0	0.48	0	0.64	0.55	0.63	1.14	13.65	0	0	0.49	0	No	No	Yes	No	0
238	0	Plastic	AcrQudLWVnl	No	0	0.48	0	0.53	0.45	0.41	0.90	13.65	0	0	0.49	0	No	No	Yes	No	0
239	0	Plastic	AcrQudBrzVnl	No	0	0.48	0	0.31	0.26	0.25	0.94	13.65	0	0	0.49	0	No	No	Yes	No	0
240	0	Plastic	AcrQudMWVnl	No	0	0.48	0	0.3	0.25	0.21	0.81	13.65	0	0	0.49	0	No	No	Yes	No	0